



AFRL-RH-WP-TR-2013-0091

Safe-to-Fly Testing of the Guardian Angel Integrated Oxygen System (GAIOS)

George W. Miller

**JULY 2013
FINAL REPORT**

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REPORT DOCUMENTATION PAGE				<i>Form Approved</i> OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</small>					
1. REPORT DATE (DD-MM-YYYY) 31-07-2013		2. REPORT TYPE Final		3. DATES COVERED (From - To) 01-06-2011 – 31-07-2013	
4. TITLE AND SUBTITLE Safe-to-Fly Testing of the Guardian Angel Integrated Oxygen System (GAIOS)				5a. CONTRACT NUMBER In-House	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 62202F	
6. AUTHOR(S) George W. Miller				5d. PROJECT NUMBER 7184	
				5e. TASK NUMBER 03	
				5f. WORK UNIT NUMBER H07Z (71840315)	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Materiel Command Air Force Research Laboratory 711 Human Performance Wing Human Effectiveness Directorate Warfighter Interface Division, 711 HPW/RHCP Wright-Patterson AFB OH 45433-7951				8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-RH-WP-TR-2013-0091	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Materiel Command Air Force Life Cycle Management Center Guardian Angel Program Office AFLCMC/WISN Wright-Patterson AFB OH 45433-7106				10. SPONSOR/MONITOR'S ACRONYM(S) AFLCMC/WISN	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES 88 ABW Cleared 10/30/2013; 88ABW-2013-4569. Report contains color.					
14. ABSTRACT 711 HPW/RHCP conducted safe-to-fly testing of the Guardian Angel Integrated Oxygen System (GAIOS). The system was comprised of the Mounted Medical Oxygen System (MMOS), Dismounted Medical Oxygen System (DMOS), and Oxygen Generating System (OGS). Testing was conducted in unmanned and manned configurations; and at ambient temperatures of Room Temperature, +130°F, and -40°F. MMOS was found safe up to a cabin altitude of 15,000 feet with up to two patients wearing standard medical masks. DMOS was found safe up to a cabin altitude of 15,000 feet with up to one patient wearing a standard medical mask. MMOS and DMOS were found safe up to a cabin altitude of 15,000 feet while supplying oxygen to one Impact 754 ventilator. During the testing MMOS and DMOS were filled with liquid oxygen conforming to 93% Oxygen U.S. Pharmacopeia (USP). The liquid oxygen was produced by a pre-production OGS.					
15. SUBJECT TERMS: Guardian Angel, MMOS, DMOS, OGS, liquid oxygen, LOX, Oxygen Generating System, safe-to-fly testing					
16. SECURITY CLASSIFICATION OF: Unclassified			17. LIMITATION OF ABSTRACT U	18. NUMBER OF PAGES 286	19a. NAME OF RESPONSIBLE PERSON George W. Miller
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (include area code)

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Acknowledgements

The author wishes to recognize the individuals listed below for their dedication and professional support during the Guardian Angel Integrated Oxygen System (GAIOS) safe-to-fly testing program. The effort was supported by USAF Contract No. FA8650-09-D-6949, Task Order 0005 with Infoscitex Corporation. Wyle Laboratories was a subcontractor under this contract.

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1.0 SUMMARY

711 HPW/RHCP conducted safe-to-fly testing of the Guardian Angel Mounted Medical Oxygen System (MMOS) and Dismounted Medical Oxygen System (DMOS). MMOS and DMOS were tested in unmanned and manned configurations; ambient temperatures of Room Temperature, +130°F, and -40°F; and altitudes up to 15,000 feet. The systems were filled with 93% Oxygen USP liquid.

a. MMOS was safe up to a cabin altitude of 15,000 feet with up to two wounded combatants wearing medical masks. MMOS should only be used in the following orientations: upright horizontal position and upright vertical position. Configuration components are noted below.

- (1) MMOS.
- (2) Seven feet of plastic tubing from MMOS barbed connector to each medical mask.
- (3) Up to two standard medical masks.

b. MMOS was safe up to a cabin altitude of 15,000 feet while supplying oxygen to one Impact 754 ventilator. MMOS should only be used in the following orientations: upright horizontal position and upright vertical position. Configuration components are noted below.

- (1) MMOS.
- (2) One medical oxygen hose from MMOS outlet to the ventilator.
- (3) One Impact 754 ventilator.

c. DMOS was safe up to a cabin altitude of 15,000 feet with one wounded combatant wearing a standard medical mask. DMOS should only be used in the following orientations: upright horizontal position, upright vertical position, and any angle between upright horizontal and upright vertical. Configuration components are noted below.

- (1) DMOS.
- (2) Seven feet of plastic tubing from DMOS barbed connector to the medical mask.
- (3) One standard medical mask.

d. DMOS was safe up to a cabin altitude of 15,000 feet while supplying oxygen to one Impact 754 ventilator. DMOS should only be used in the following orientations: upright horizontal position, upright vertical position, and any angle between upright horizontal and upright vertical. Configuration components are noted below.

- (1) DMOS.
- (2) One medical oxygen hose from the DMOS outlet to the ventilator inlet connection.
- (3) One Impact 754 ventilator.

2.0 INTRODUCTION

The Guardian Angel Integrated Oxygen System (GAIOS) is a family of systems designed to improve the capabilities of pararescue, CSAR, and special operations personnel. The oxygen

systems include the Mounted Medical Oxygen System (MMOS), Dismounted Medical Oxygen System (DMOS), and Oxygen Generating System (OGS). The MMOS is an aircraft-mounted system and the DMOS is a portable system. OGS is a ground-based system for generating liquid oxygen and filling the MMOS and DMOS with oxygen conforming to the 93% Oxygen USP standard. The goal of the Guardian Angel program is to improve oxygen availability on the battlefield.

3.0 METHODS

3.1 Test Article Description

MMOS is designed to provide oxygen to up to two wounded combatants (see Fig.1). MMOS has a liquid oxygen converter with a heat exchanger, pressure regulator, flow control valves, and flow distribution hardware. MMOS was designed to operate in the horizontal and vertical orientations. The MMOS has two flow controlled outlets and two DISS 1240 (50 psig) accessory ports. The two 12-position flow control valves control the outlet flow rates (15 liters/minute maximum) to two barb-type outlet ports. Commercially available medical masks, cannulas, and bag-valve masks can be connected to these barbed ports. A pressure gauge monitors oxygen supply pressure. MMOS has a digital LOX quantity display. The filled unit weighs about 30 lbs and has a 4.2 liter liquid oxygen converter. MMOS is designed for use on helicopter and fixed wing aircraft.



Figure 1. Mounted Medical Oxygen System (MMOS)

DMOS is designed to provide oxygen to one wounded combatant (see Fig. 2). DMOS has a liquid oxygen converter with a heat exchanger, pressure regulator, flow control valve, and flow distribution hardware. DMOS has one flow controlled outlet (15 liters/minute maximum), one standard DISS connector, and a port labeled “Parachutist.” Commercially available medical masks, cannulas, and bag-valve masks can be connected to the barbed port. A pressure gauge monitors oxygen supply pressure. The device has a digital LOX quantity display. The filled unit weighs about 16 lbs and has a 1.4 liter liquid oxygen converter. DMOS is installed in a canvass pouch and designed for use on helicopter and fixed wing aircraft. DMOS was designed to operate in five positions: horizontal, vertical, upside down vertical, right side down, and left side down. DMOS was not designed to operate in the upside side down horizontal position.



Figure 2. Dismounted Medical Oxygen System (DMOS)

The OGS (see Fig. 3) is a ground-based, skid-mounted device designed to generate, liquefy, and store 93% Oxygen USP. The unit has a molecular sieve oxygen generator, an oxygen liquefier, and a LOX storage container. The OGS is used to fill the MMOS and DMOS. MMOS and DMOS may also be filled by a standard LOX cart. The OGS used for this testing was a pre-production unit.



Figure 3. Oxygen Generating System (OGS)

3.2 Scope

The intent of the effort was to test the MMOS and DMOS in an altitude chamber up to a maximum altitude of 40,000 feet in an unmanned configuration and up to a maximum altitude of 15,000 feet in a manned configuration. Manned testing commenced after the unmanned testing was completed. The OGS oxygen was sampled periodically and tested. Also, an empty and non-operational OGS was exposed to an altitude of 40,000 feet to verify the system would function properly after returning to Ground Level. For informational purposes only, limited testing was accomplished with a Phantom parachutist mask but there is no plan to use the DMOS for parachuting. The DMOS parachuting capability was deleted from the program just prior to testing. For informational purposes only, the DMOS was tested in the upside down horizontal orientation. There was no plan to use DMOS in this orientation.

The effort was evaluated by the AFRL Institutional Review Board (IRB) and they determined the effort was “not human use research based on CFR 219.102 (d) (f) and AFI 40-402 (Attachments 12 and 13). The effort was categorized as test and evaluation.

4.0 RESULTS

4.1 MMOS Unmanned Testing Summary. The purpose of the unmanned engineering testing was to show the system is safe and effective prior to beginning manned testing. The specific test conditions are described below (see Para. 4.1.1-4.1.16). The data plots for these test conditions are at Appendix A, Figures A-1-A-52. The system minimum and maximum flow

specifications are noted on the figures by broken lines. MMOS was tested at Room Temperature, +130°F, and -40°F.

4.1.1 Data for unmanned testing at altitude, room temperature, horizontal orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-1-A-4. MMOS met the system flow specification.

- a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.
- b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.2 Data for unmanned testing at altitude, room temperature, horizontal orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-5-A-8. MMOS met the system flow specification.

- a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.
- b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.3 Data for unmanned testing at altitude, room temperature, vertical orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-9-A-12. MMOS met the system flow specification.

- a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.
- b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.4 Data for unmanned testing at altitude, room temperature, vertical orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-13-A-16. MMOS met the system flow specification.

- a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.
- b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.5 Data for unmanned testing at altitude, +130°F, horizontal orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-17-A-20. MMOS met the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.6 Data for unmanned testing at altitude, +130°F, horizontal orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-21-A-24. MMOS met the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.7 Data for unmanned testing at altitude, +130°F, vertical orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-25-A-28. MMOS met the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.8 Data for unmanned testing at altitude, +130°F, vertical orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-29-A-32. MMOS met the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.9 Data for unmanned testing at altitude, -40°F, horizontal orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-33-A-36. MMOS was slightly below the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.10 Data for unmanned testing at altitude, -40°F, horizontal orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-37-A-40. MMOS was slightly below the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.11 Data for unmanned testing at altitude, -40°F, vertical orientation, and flow selectors set to 8 LPM are at Appendix A, Figures A-41-A-44. MMOS met the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.12 Data for unmanned testing at altitude, -40°F, vertical orientation, and flow selectors set to 15 LPM are at Appendix A, Figures A-45-A-48. MMOS was slightly below the system flow specification.

a. Test altitudes: Ground Level, 5, 000 feet, 10,000 feet, and 15,000 feet.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.13 Data for unmanned testing, decompression to 40,000 feet, room temperature, horizontal orientation, and flow selectors set to 8 LPM are at Appendix A, Figure A-49. MMOS continued to provide adequate flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.14 Data for unmanned testing, decompression to 40,000 feet, room temperature, horizontal orientation, and flow selectors set to 15 LPM are at Appendix A, Figure A-50. MMOS continued to provide adequate flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.15 Data for unmanned testing, decompression to 40,000 feet, room temperature, vertical orientation, and flow selectors set to 8 LPM are at Appendix A, Figure A-51. MMOS continued to provide adequate flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.1.16 Data for unmanned testing, decompression to 40,000 feet, room temperature, vertical orientation, and flow selectors set to 15 LPM are at Appendix A, Figure A-52. MMOS continued to provide adequate flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow Port #1, Outlet Flow Port #2, Outlet Temperature Port #1, Outlet Temperature Port #2, Outlet Temperature at End of Delivery Hose Port #1, Outlet Temperature at End of Delivery Hose Port #2, Supply Pressure.

4.2 MMOS Unmanned Testing Pass/Fail Criteria Results.

4.2.1 Success Criterion #1: OGS oxygen samples shall comply with 93% Oxygen USP standard.

PASS – Analysis showed OGS oxygen samples passed the 93% USP standard (Appendix G, Lab Reports 2011LA35124001, 2011LA35287001, 2012LA35443001, and 2012LA35603001).

4.2.2 Success Criterion #2: MMOS oxygen gas concentration when measured with a mass spectrometer shall be $93\pm3\%$.

PASS – The MMOS oxygen concentration was checked before each data run with a mass spectrometer and the oxygen concentration was within $93\pm3\%$.

4.2.3 Success Criterion #3: Flow rate delivered at Ground Level shall be within 8 \pm 1.60 LPM and 15 \pm 2.5 LPM. At altitude the settings of 8 LPM and 15 LPM MMOS shall produce a flow above 6.4 ALPM and 12.5 ALPM, respectively.

FAIL – In 45 of 48 test conditions the MMOS successfully met the success criterion. In three tests at Ground Level and the extreme low temperature of -40°F (see Figures A-33, A-37, and A-45) the outlet flow rate was slightly under the success criterion.

Note: At Ground Level, -40°F, horizontal orientation, and 8 LPM setting the percentage difference between the specification and the actual flow was 1.6% (Figure A-33). At Ground Level, -40°F, horizontal orientation, and 15 LPM setting the percentage difference between the specification and the actual flow was 6.4% (Figure A-37). At Ground Level, -40°F, vertical orientation, and 15 LPM setting the percentage difference between the specification and the actual flow was 8.0% (Figure A-45). Because the outlet flow rate was only slightly below the success criterion and only at the extreme operating temperature condition (-40°F), it was determined these deviations were minimal and acceptable.

4.2.4 Success Criterion #4: Temperature of the oxygen at the mask at altitudes of 15,000 feet and below shall not be greater than 20°F below ambient chamber temperature when measured at the outlet of the delivery hose.

PASS – The temperature of the oxygen at the mask was never greater than 20°F below ambient temperature.

4.2.5 Success Criterion #5: The MMOS shall deliver adequate oxygen flow during and after a decompression to 40,000 feet and upon return to 8,000 feet altitude.

PASS – The MMOS continued to deliver adequate oxygen flow during and after the decompressions to 40,000 feet and upon return to 8,000 feet altitude.

4.2.6 Success Criterion #6: The MMOS shall not leak; have any mechanical or electrical failures; or any safety issues.

PASS – The MMOS did not leak; have any mechanical or electrical failures; or any safety issues.

4.3 MMOS Manned Testing Summary. MMOS was evaluated during ten manned altitude chamber tests. Maximum altitude for the testing was 15,000 feet. The data runs are summarized below. Participants were pararescuemen (PJs). An experienced physiology technician (PT) served as an inside observer and equipment operator when the participants wore medical masks supplied with oxygen from the MMOS (see Fig. 4). One of the medical masks was instrumented. The instrumented mask was the exact same model as the other mask but was modified to measure the mask oxygen concentration (see Fig. 5). The temperature of the oxygen flowing to both masks was measured. Several times during the testing the participants' blood oxygen saturation percentage was measured by a fingertip pulse oximeter. During the MMOS testing with a ventilator a pararescueman operated the ventilator and breathed from the chamber oxygen system. The ventilator was operated over a range of flow settings. No one breathed from the ventilator.



Figure 4. MMOS manned testing in-progress



Figure 5. Instrumented medical mask showing oxygen concentration sample tubing

4.3.1 MMOS Manned Run #1: This test investigated the minimum flow setting for a horizontally oriented MMOS needed to maintain Ground Level blood oxygen saturation

percentage at 15,000 feet. The intent was to provide this minimum flow setting information to the users as general guidance when operating at aircraft cabin altitudes between 10,000 and 15,000 feet. Pararescuemen receive medical training and will administer oxygen as they deem necessary. The chamber was at Room Temperature and 15,000 feet. Two participants breathed from standard medical masks connected to the MMOS. The oxygen flow settings were incrementally decreased until the blood oxygen saturation percentage fell below the participants' Ground Level blood oxygen saturation, then the flow settings were increased until the blood oxygen saturation percentage returned to their normal Ground Level blood oxygen saturation. Data plot for Run #1 is at Appendix B, Figure B-1. Ground Level blood oxygen saturations for Participant #1 and Participant #2 prior to the run were 99% and 98%, respectively. The MMOS flow settings were incrementally decreased to 3 LPM. Participant #1 blood oxygen saturation dropped to 98%. Participant #2 blood oxygen saturation dropped to 97%. Flow settings were gradually increased until the participants' blood oxygen saturations returned to their normal Ground Level oxygen saturation. Participant #1 returned to Ground Level blood oxygen saturation at a flow of 8 LPM. Participant #2 returned to Ground Level equivalency at a flow setting of 4 LPM. Breathing rate, mask leakage, and other individual variables led to differences in oxygen flow needed to achieve Ground Level blood oxygen saturation while at altitude. The goal was to determine the highest flow needed based on four participants (two participants in Run #1 and two participants in Run #2). The instrumented mask's real time oxygen concentration varied between about 27% and 94% during the run. Wide variations in mask oxygen concentration are expected because the medical masks do not provide a tight seal and ambient air can leak into the mask. The average mask oxygen concentration was measured using 15 second time averaging. MMOS supply pressure (pressure upstream of the flow selector switch) varied between 48 and 50 psig. Mask oxygen temperatures were slightly (1 to 3°F) above ambient temperature. Liquid level sensing subsystem was not working properly during this run. Participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and oxygen temperature was acceptable.

4.3.2 MMOS Manned Run #2: This test was a repeat of Run #1, except the MMOS was in the vertical configuration. Goal was to continue to investigate the minimum flow setting needed to maintain Ground Level blood oxygen saturation percentage at 15,000 feet. Data plot for Run #2 is at Appendix B, Figure B-2. The Ground Level blood oxygen saturation for Participant #1 and Participant #2 prior to the run was 98%. The MMOS flow settings were incrementally decreased to 3 LPM. At this setting the blood oxygen saturation for Participant #1 and Participant #2 were 96% and 94%, respectively. The flow settings were incrementally increased and Participant #1 blood oxygen saturation returned to Ground Level equivalency at a flow setting of 5 LPM. Participant #2 blood oxygen saturation returned to Ground Level oxygen saturation at a flow setting of 12 LPM. The instrumented mask's real time oxygen concentration varied between about 23% and 95% during the run. MMOS supply pressure varied between 47 and 51 psig. Mask oxygen temperatures were slightly (2 to 10°F) above ambient temperature. The LOX% (liquid level) reading was not working during the run. Based on Runs #1 and #2, it was concluded a minimum flow setting of 12 LPM will be provided as guidance when operating between cabin altitudes of 10,000 feet and 15,000 feet. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and oxygen temperature was acceptable.

4.3.3 MMOS Manned Run #3: This test investigated the performance of a horizontally oriented MMOS at Ground Level, 5,000 feet, 10,000 feet, and 15,000 feet. The chamber was at Room Temperature. Two participants wore standard medical masks. Data run for Run #3 is at Appendix B, Figure B-3. The Ground Level blood oxygen saturation for Participant #1 and Participant #2 prior to the run was 98% and 97%, respectively. At each altitude the MMOS flow selector was set to 12 LPM and 15 LPM. The goal was to ensure at each altitude the participants' blood oxygen saturation remained at or above their Ground Level blood oxygen saturation. The blood oxygen saturation of Participant #1 was constant at 98% throughout the run. The blood oxygen saturation of Participant #2 was at 98% throughout the run (one reading was at 97%). The instrumented mask's oxygen concentration varied between about 27% and 94% during the run. MMOS supply pressure varied between 48 and 51 psig. Mask oxygen temperatures were at or slightly (3°F) above ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. It was concluded flow settings of 12 LPM and 15 LPM provided sufficient oxygen to maintain Ground Level blood oxygen saturation at the operating altitudes. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and oxygen temperature was acceptable.

4.3.4 MMOS Manned Run #4: This test exposed a horizontally oriented MMOS to an ambient temperature of +130°F at Ground Level only. Testing at altitude and +130°F was unwarranted and it would have posed additional risk for the participants. Additionally, the time period for this test was limited to minimize participant risk. Two participants wore medical masks. Data plot for Run #4 is at Appendix B, Figure B-4. The Ground Level blood oxygen saturations for Participant #1 and Participant #2 prior to the run were 96% and 97%, respectively. Flow settings were 12 LPM and 15 LPM. The blood oxygen saturation of Participant #1 rose to 98% and remained at that level throughout the run. The blood oxygen saturation of Participant #2 rose to and remained at 98% throughout the run, except one data point at 99%. The instrumented mask's real time oxygen concentration varied between 56% and 94%. MMOS supply pressure was about 50 psig. Mask oxygen temperatures were about 5°F below ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow. One participant felt the oxygen temperature was acceptable and the same as the ambient temperature. The other participant noted the oxygen temperature was a little warm but acceptable. The oxygen temperature would be expected to be near ambient temperature because the flexible hose between the MMOS and the oxygen mask will warm the oxygen to near ambient temperature.

4.3.5 MMOS Manned Run #5: This test investigated the performance of a vertically oriented MMOS at Ground Level, 5,000 feet, 10,000 feet, and 15,000 feet. The chamber was at Room Temperature. Two participants wore standard medical masks. Data run for Run #5 is at Appendix B, Figure B-5. The Ground Level blood oxygen saturation for Participant #1 and Participant #2 prior to the run was 98% and 97%, respectively. At each altitude the MMOS flow settings were set to 12 LPM and 15 LPM. The goal was to ensure at each altitude the participants' blood oxygen saturation was at or above their Ground Level blood oxygen saturation percentage. The blood oxygen saturation of Participant #1 was at 98-99% throughout the run. The blood oxygen saturation of Participant #2 was at 98-99% throughout the run. The

instrumented mask's oxygen concentration varied between about 26% and 94%. MMOS supply pressure varied between 48 and 51 psig. Mask oxygen temperatures were within 3°F of ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. It was concluded flow settings of 12 LPM and 15 LPM provided sufficient oxygen to maintain Ground Level blood oxygen saturation at the operating altitudes. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and oxygen temperature was acceptable.

4.3.6 MMOS Manned Run #6: This test exposed a vertically oriented MMOS to an ambient temperature of +130°F at Ground Level only. Two participants wore medical masks. Data plot for Run #6 is at Appendix B, Figure B-6. The Ground Level blood oxygen saturations for Participant #1 and Participant #2 prior to the run were at 97%. MMOS flow settings were 12 LPM and 15 LPM. The blood oxygen saturation of Participant #1 and Participant #2 rose to 98% and remained constant. The instrumented mask's real time oxygen concentration varied between 27% and 94%. MMOS supply pressure was about 50 psig. Mask oxygen temperatures were about 4°F below ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow. One participant noted the oxygen temperature was acceptable but seemed warmer than previously experienced with cylinders. The other participant noted the oxygen temperature was acceptable but seemed a lot warmer than past experience with pressurized oxygen. The oxygen temperature would be expected to be near ambient temperature because the flexible hose between the MMOS and the oxygen mask would allow the oxygen to warm to near ambient temperature.

4.3.7 MMOS Manned Run #7: During this test the horizontally oriented MMOS supplied oxygen to an Impact 754 ventilator. The goal was to assess performance of the MMOS when supplying oxygen to a ventilator. The specific ventilator settings used are in Table 1. The paramedics determined the test settings. The 400 mL setting simulated a pediatric setting. The 600 mL setting was considered nominal. The settings of 1000 and 3000 mL were applied to test the MMOS at higher flows. The altitude chamber was at Room Temperature. The participants operated the ventilator and breathed from the chamber oxygen system. No one was breathing from the ventilator. MMOS was tested at Ground Level and an altitude of 15,000 feet. The data plot for Run #7 is at Appendix B, Figure B-7. At Ground Level the MMOS outlet pressure varied between 40 and 52 psig. At 15,000 feet the MMOS outlet pressure varied between 44 and 52 psig. The ventilator has a low inlet pressure warning of 35 psig. The temperature of the oxygen at the ventilator inlet at Ground Level was close to ambient temperature. At 15,000 feet the ventilator inlet temperature was about 5°F below ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaires are at Appendix C. Both paramedics indicated the ventilator appeared to operate normally.

Table 1. Ventilator Settings

Tidal Volume (mL)	Breaths/minute
400	34
600	15
1000	20
3000	15

4.3.8 MMOS Manned Run #8: This test exposed a horizontally oriented MMOS to an ambient temperature of -40°F at Ground Level only. Testing at -40°F and at altitude was unwarranted and it posed additional risk for the participants. Also, the testing time period was limited to reduce participant risk. Two participants wore medical masks and cold weather gear. Data plot for Run #8 is at Appendix B, Figure B-8. Flow settings of 12 LPM and 15 LPM were used. The blood oxygen saturations of Participant #1 and Participant #2 were 98-99% throughout the run. The instrumented mask's real time oxygen concentration varied between about 36% and 94% during the run. MMOS supply pressure was about 50 psig. Mask oxygen temperatures were at or slightly (2-3°F) above ambient temperature. The battery life percentage (BAT%) gave very low readings (near 0%) during the run, however, the liquid oxygen level (LOX%) appeared to function normally. Both rebreather bags on the medical masks cracked and split open due to the low operating temperature. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and oxygen temperature was acceptable. One participant noted the oxygen temperature seemed near the chamber temperature. The oxygen temperature would be expected to be near ambient temperature because the flexible hose between the MMOS and the oxygen mask will allow the oxygen temperature to approach the ambient temperature.

4.3.9 MMOS Manned Run #9: During this test the vertically oriented MMOS supplied oxygen to an Impact 754 ventilator. The specific ventilator settings used are at Table 1. The paramedics determined the settings. The 400 mL setting simulated a pediatric setting. The 600 mL setting was considered nominal. The settings of 1000 and 3000 mL were applied to test the MMOS at higher flows. The altitude chamber was at Room Temperature. The participants operated the ventilator and breathed from the chamber oxygen system. No one was breathing from the ventilator. MMOS was tested at Ground Level and an altitude of 15,000 feet. The data plot for Run #9 is at Appendix B, Figure B-9. At Ground Level the MMOS outlet pressure varied between 40 and 52 psig. At 15,000 feet the MMOS outlet pressure varied between 44 and 52 psig. The temperature of the oxygen at the ventilator inlet at Ground Level and 15,000 feet was about 5°F below the ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaires are at Appendix C. Both paramedics indicated the ventilator appeared to operate normally when connected to the MMOS.

4.3.10 MMOS Manned Run #10: This test exposed a vertically oriented MMOS to an ambient temperature of -40°F at Ground Level only. Two participants wore medical masks and cold weather gear. Data plot for Run #10 is at Appendix B, Figure B-10. The Ground Level blood oxygen saturations for Participant #1 and Participant #2 prior to the run were 99% and 97%, respectively. Flow settings were 12 LPM and 15 LPM. The blood oxygen saturation of

Participant #1 remained at 99% during the run. Blood oxygen saturation for Participant #2 rose to 98% and was constant throughout the run. The instrumented mask's real time oxygen concentration varied between about 39% and 94% during the run. MMOS supply pressure was about 50 psig. Mask oxygen temperatures were at or slightly (2-3°F) above ambient temperature. The battery life percentage (BAT%) appeared to read near 0% during the run. Liquid oxygen level (LOX%) appeared to function normally most of the time. For a short time (several seconds) the LOX% was inoperative. One rebreather bag on a medical mask cracked and split open due to the low temperature. The participant questionnaires are at Appendix C. The participants indicated the system provided adequate flow and the oxygen temperature. One participant felt the oxygen temperature was slightly colder than the ambient temperature but it was not an issue. The other participant felt the oxygen was at the same temperature as the chamber.

4.4 MMOS Manned Testing Pass/Fail Criteria Results.

4.4.1 Success Criterion #1: OGS oxygen samples shall comply with 93% Oxygen USP standard.

PASS - The OGS samples passed the USP standard. Analysis showed OGS oxygen samples passed the 93% USP standard (Appendix G, Lab Reports 2011LA35124001, 2011LA35287001, 2012LA35443001, and 2012LA35603001).

4.4.2 Success Criterion #2: Temperature of oxygen delivered to mask shall not be greater than 20°F below chamber temperature.

PASS – Mask temperatures were less than 20°F below chamber temperature.

4.4.3 Success Criterion #3: Blood oxygen saturation shall be $\geq 95\%$.

PASS – Blood oxygen saturation was greater than 95% when using the minimum flow selector setting, 12 LPM. When operating above 10,000 feet the minimum flow selector setting recommended is 12 LPM.

4.4.4 Success Criterion #4: MMOS shall interface properly to Impact 754 ventilator, supply pressure of 50 ± 5 psig shall be maintained, and ventilator oxygen delivery temperature shall not be greater than 20°F below ambient chamber temperature.

FAIL – The MMOS interfaced properly to the Impact 754 ventilator. The supply pressure did drop below 50 ± 5 psig. The lowest pressure observed was 40 psig. The ventilator oxygen delivery temperature was not greater than 20°F below ambient chamber temperature.

Note: Although the lowest pressure observed was 40 psig, the Impact 754 ventilator has a low pressure warning set point at 35 psig. Because the lowest MMOS delivery pressure was above the ventilator pressure warning set point, the performance of the MMOS was deemed acceptable.

4.4.5 Success Criterion #5: Impact 754 ventilator shall operate normally at Ground Level, 15,000 feet, and during ascent and descent.

PASS – The Impact 754 ventilator operated normally at Ground Level, 15,000 feet, and during ascent and descent.

4.5 DMOS Unmanned Testing Summary. Purpose was to conduct DMOS unmanned engineering tests to show the system was safe and effective prior to beginning manned testing. Test data are at Appendix D. DMOS was placed inside its pouch during the testing (see Fig. 6). During the high flow testing at 30 LPM an external flow control valve was connected at the auxiliary port. Several OGS oxygen samples were sent for lab analysis. The analysis ensured the OGS oxygen complied with the 93% Oxygen USP standard. The testing was conducted in six orientations: horizontal, 45 degree, vertical, upside down vertical, right side down, and left side down. Testing was conducted at upside down horizontal orientation for informational purposes only. The outlet flow selectors (i.e. internal selector and external selector) were set to 15 LPM when a total flow of 30 LPM was desired and the DMOS internal selector was set to 15 LPM when a total flow of 15 LPM was desired. The system minimum and maximum flow specifications are noted in the figures. DMOS was tested at Room Temperature, +130°F, and -40°F.

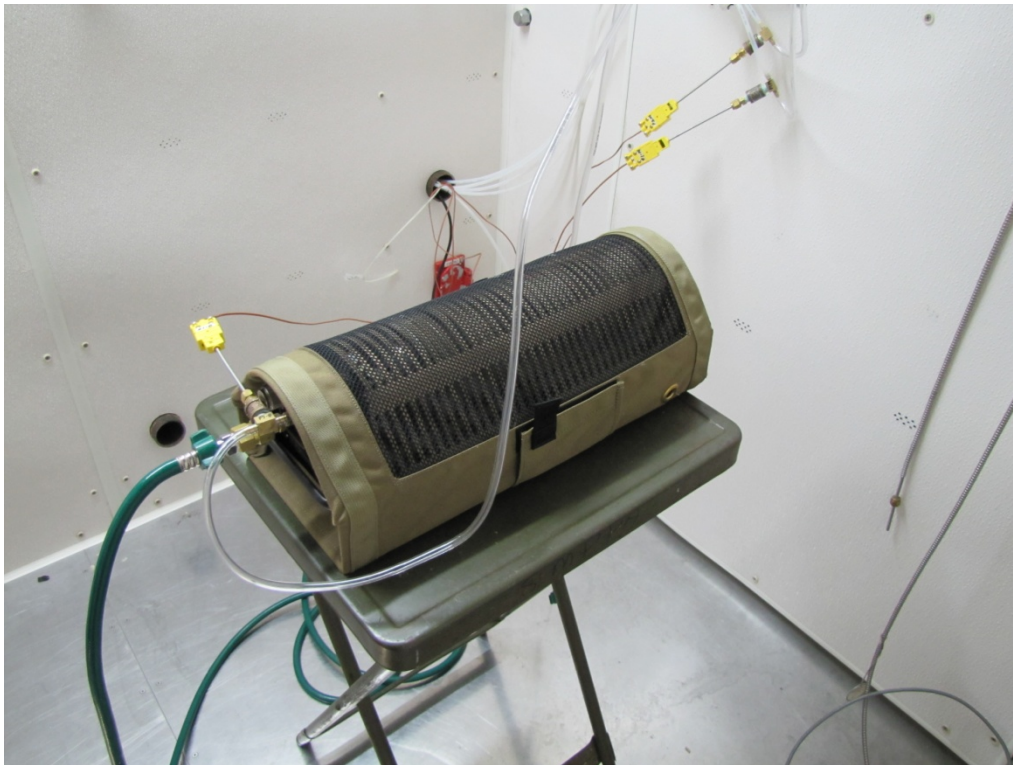


Figure 6. DMOS unmanned testing in-progress

4.5.1 Data for unmanned testing at altitude, room temperature, horizontal orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM.) are at Appendix D, Figures D-1-D-3. DMOS produced a flow within the system specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.2 Data for unmanned testing at altitude, room temperature, upside down horizontal orientation (For Informational Purposes Only), and flow selectors set to 15 LPM (Total flow was 30 LPM.) are at Appendix D, Figures D-4-D-6. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.3 Data for unmanned testing at altitude, room temperature, vertical orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM.) are at Appendix D, Figures D-7-D-9. DMOS produced an outlet flow that met the system flow specification.

- a. Test altitudes: Ground Level, 8, 000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.4 Data for unmanned testing at altitude, room temperature, upside down vertical orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM.) are at Appendix D, Figures D-10-D-12. DMOS failed the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.5 Data for unmanned testing at altitude, room temperature, right side down orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM.) are at Appendix D, Figures D-13-D-15. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.6 Data for unmanned testing at altitude, room temperature, left side down orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-16-D-18. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.7 Data for unmanned testing at altitude, room temperature, horizontal orientation, and flow selector set to 15 LPM (Total flow was 15 LPM.) are at Appendix D, Figures D-19-D-21. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.8 Data for unmanned testing at altitude, room temperature, vertical, and flow selector set to 15 LPM (Total flow was 15 LPM.) are at Appendix D, Figures D-22-D-24. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperatures, Outlet Temperatures at End of 7 foot Delivery Hose, Supply Pressure.

4.5.9 Data for unmanned testing at altitude, room temperature, upside down horizontal (For Informational Purposes Only), and flow selector set to 15 LPM (Total flow was 15 LPM.) are at Appendix D, Figures D-25-D-27. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8, 000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.10 Data for unmanned testing at altitude, room temperature, upside down vertical orientation, and flow selector set to 15 LPM (Total flow was 15 LPM.) are at Appendix D, Figures D-28-D-30. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.11 Data for unmanned testing at altitude, room temperature, right side down orientation, and flow selector set to 15 LPM (Total flow was 15 LPM.) are at Appendix D, Figures D-31-D-33. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.12 Data for unmanned testing at altitude, room temperature, right side down orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-34-D-36. This testing was accomplished with a second DMOS. DMOS passed the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.13 Data for unmanned testing at altitude, room temperature, left side down orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-37-D-39. DMOS met the system flow specifications.

a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.14 Data for unmanned testing at altitude, room temperature, 45 degrees orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-40-D-42. DMOS met the system flow specification.

a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.15 Data for unmanned testing at altitude, room temperature, 45 degrees orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-43-D-45. DMOS met the system flow specification.

a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.16 Data for unmanned testing at altitude, 130°F, horizontal, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-46-D-48. DMOS met the system flow specification.

a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.17 Data for unmanned testing at altitude, 130°F, horizontal, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-49-D-51. DMOS met the system flow specifications.

a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.18 Data for unmanned testing at altitude, 130°F, vertical, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-52-D-54. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.19 Data for unmanned testing at altitude, 130°F, vertical, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-55-D-57. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.20 Data for unmanned testing at altitude, 130°F, 45 degree orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-58-D-60. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.21 Data for unmanned testing at altitude, 130°F, 45 degrees orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-61-D-63. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses 1 and 2, Supply Pressure.

4.5.22 Data for unmanned testing, decompression to 40,000 feet, room temperature, horizontal orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figure D-64. DMOS continued to provide flow during and after the decompression.

- a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.23 Data for unmanned testing, decompression to 40,000 feet, room temperature, horizontal orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figure D-65. DMOS continued to provide flow during and after the decompression.

- a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.24 Data for unmanned testing, decompression to 40,000 feet, room temperature, vertical orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figure D-66. DMOS continued to provide flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.25 Data for unmanned testing, decompression to 40,000 feet, room temperature, vertical orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figure D-67. DMOS continued to provide flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.26 Data or unmanned testing, decompression to 40,000 feet, room temperature, 45 degree orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figure D-68. DMOS continued to provide flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.27 Data for unmanned testing, decompression to 40,000 feet, room temperature, 45 degree orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figure D-69. DMOS continued to provide flow during and after the decompression.

a. Decompress from 8,000 feet to 40,000 feet in 7 seconds and hold at 40,000 feet for 2 minutes. Descend to 8,000 feet at a standard rate. Hold at 8,000 feet until data stabilizes, then descend to Ground Level.

b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.28 Data for unmanned testing at altitude, -40°F, horizontal orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-70-D-72. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.29 Data for unmanned testing at altitude, -40°F, horizontal orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-73 and D-74. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.30 Data for unmanned testing at altitude, -40°F, horizontal orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-75-D-77. A second unit was tested. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.31 Data for unmanned testing at altitude, -40°F, vertical orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-78-D-80. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.32 Data for unmanned testing at altitude, -40°F, 45 degree orientation, and flow selector set to 15 LPM (Total flow was 15 LPM) are at Appendix D, Figures D-81-D-83. DMOS met the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flow, Outlet Temperature, Outlet Temperature at End of 7 foot Delivery Hose, Supply Pressure.

4.5.33 Data for unmanned testing at altitude, -40°F, 45 degree orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-84 and D-85. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.

- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.34 Data for unmanned testing at altitude, -40°F, vertical orientation, and flow selectors set to 15 LPM (Total flow was 30 LPM) are at Appendix D, Figures D-86-D-88. DMOS failed to meet the system flow specification.

- a. Test altitudes: Ground Level, 8,000 feet, and 15,000 feet.
- b. Data: Outlet Flows 1 and 2, Outlet Temperatures 1 and 2, Outlet Temperatures at End of 7 foot Delivery Hoses, Supply Pressure.

4.5.35 Unmanned Phantom Mask Testing (For Informational Purposes Only): Purpose was to conduct limited unmanned tests with the Phantom mask (see Fig. 7). The Phantom breathing regulator is mounted on the mask. The limited test conditions are listed below. The data plots for this testing are at Appendix D, Figures D-89-D-130. Figures D-89-D-124 show the real time performance data for the Phantom Mask. A range of peak flows were used to assess breathing impedance and oxygen delivery. Figures D-125-D-130 show the mask pressures observed for the test conditions. The breathing performance is plotted versus the desired mask pressures for a breathing regulator. The mask pressures and pressure swings are within standards under most conditions. However, at the high peak flow rate of 200 liters/minute the mask pressure is slightly outside the desired pressures at Ground Level (see Appendix D, Figs. D-125, D-127, and D-129). Under most conditions the oxygen concentration delivered is adequate. However, at the low flow of 17 LPM peak flow and altitudes of 15,000 feet and 20,000 feet the oxygen concentration percentage delivered was below the required concentration. At 15,000 feet and 20,000 feet the minimum oxygen concentration should be 38% and 48%, respectively. The Phantom mask delivered 32% oxygen at 15,000 feet and 34% oxygen at 20,000 feet when DMOS was in the horizontal orientation (see Figs. D-107 and D-110). DMOS orientations (horizontal, vertical, and 45 degree) had negligible impact on system performance.

- a. Test altitudes: Ground Level, 8,000 feet, 15,000 feet, and 20,000 feet.
- b. Room Temperature.
- c. Horizontal, Vertical, and 45 Degree configurations.
- d. Data: Mask Pressure, Mask Oxygen Concentration, Mask Temperature, and Supply Pressure.
- e. Breathing machine settings:
 - (1) 17 liters/minute and 8 breaths/minute.
 - (2) 125 liters/minute and 40 breaths/minute.
 - (3) 200 liters/minute and 50 breaths/minute.



Figure 7. Phantom parachutist mask

4.5.36 Unmanned OGS Testing: Purpose was to verify an empty and non-operating OGS can be decompressed to 40,000 feet and then operate normally when returned to Ground Level (see Fig. 8). The altitude chamber ascended to 8,000 feet. The chamber was decompressed to 40,000 feet and remained at 40,000 feet for 15 minutes. The chamber was descended to 8,000 feet and remained at 8,000 feet for 15 minutes. The chamber descended to Ground Level. The OGS was removed from the chamber, shipped to Nellis AFB NV, and operationally tested at Ground Level. Nellis AFB personnel reported the OGS functioned properly.



Figure 8. OGS altitude testing in-progress

4.6 DMOS Unmanned Testing Pass/Fail Criteria Results.

4.6.1 Success Criterion #1: OGS oxygen samples shall comply with 93% Oxygen USP standard.

PASS – Analysis showed the OGS oxygen samples passed the 93% USP oxygen standard (see Appendix G; Lab Reports 2012LA40749001, 2012LA40907001, 2012LA41088001, and 2012LA41088002).

4.6.2 Success Criterion #2: DMOS oxygen gas concentration when measured with a mass spectrometer shall be $93 \pm 3\%$.

PASS - The oxygen concentration was checked before each data run with a mass spectrometer and the oxygen concentration was within $93 \pm 3\%$.

4.6.3 Success Criterion #3: Flow rate delivered at Ground Level shall be within 15 ± 2.5 LPM. At altitude the flow shall be above 12.5 ALPM.

FAIL – The failure conditions are noted in Table 2. DMOS was designed for operation in all orientations, except upside down horizontal. Room temperature testing showed flow failures in the upside down vertical and right side down orientations. Based on these results, it was decided to limit DMOS orientations to horizontal, vertical, and 45 degrees. Also, the right

side down flow failure drove a decision to remove both side down orientations from the testing. Further, flow failures in the two outlet configuration (internal and external flow selectors; total flow of 30 liters/minute) and -40°F forced a decision to eliminate this configuration from consideration.

Note: Performance of the system was adequate in the one outlet configuration (total flow of 15 liters/minute); and horizontal, vertical, and 45 degree orientations.

Table 2. DMOS Flow Testing Pass/Fail Outcomes

	Horizontal	Upside Down Horizontal	Vertical	Upside Down Vertical	Right Side Down	Left Side Down	45 Degrees
Room Temp.							
30 LPM	Pass	Fail (Info Only)	Pass	Fail	Pass	Pass	Pass
15 LPM	Pass	Fail (Info Only)	Pass	Fail	Fail	Pass	Pass
+130°F							
30 LPM	Pass	Not Tested	Pass	Not Tested	Not Tested	Not Tested	Pass
15 LPM	Pass	Not Tested	Pass	Not Tested	Not Tested	Not Tested	Pass
-40°F							
30 LPM	Fail	Not Tested	Fail	Not Tested	Not Tested	Not Tested	Fail
15 LPM	Pass	Not Tested	Pass	Not Tested	Not Tested	Not Tested	Pass

4.6.4 Success Criterion #4: Oxygen supplied by the DMOS at altitudes up to 15,000 feet shall not be greater than 20°F below ambient chamber temperature at the outlet of the delivery hose.

PASS – The temperature of the oxygen at the mask was never greater than 20°F below ambient temperature.

4.6.5 Success Criterion #5: DMOS shall deliver oxygen during and after a decompression to 40,000 feet, upon return to 8,000 feet altitude, and upon return to Ground Level.

PASS – DMOS continued to deliver oxygen during and after the decompressions to 40,000 feet and upon return to 8,000 feet altitude.

4.6.6 Success Criterion #6: DMOS shall not leak; have any mechanical or electrical failures; or any safety issues.

PASS – DMOS did not leak; have any mechanical or electrical failures; or any safety issues.

4.6.7 Success Criterion #7: The OGS shall be fully functional at Ground Level after an exposure to an altitude of 40,000 feet.

PASS – The OGS was fully functional after returning to Ground Level. The Ground Level functional test was performed at Nellis AFB.

4.7 DMOS Manned Testing Summary.

DMOS was evaluated during eight manned altitude chamber tests. Based on the unmanned testing results, orientations used were: horizontal, vertical, and 45 degree. Maximum altitude for the testing was 15,000 feet. The data runs are summarized below. Participants were pararescuemen (PJs). An experienced physiology technician (PT) served as an inside observer and equipment operator when the participant wore a medical mask supplied with oxygen from the DMOS. The medical mask was instrumented to measure oxygen concentration. Also, the temperature of the oxygen flowing to the mask was measured. Several times during the testing the participant's blood oxygen saturation percentage was measured by a fingertip pulse oximeter. During the DMOS and ventilator testing a pararescueman operated the ventilator. The participant breathed oxygen from the chamber oxygen system. The ventilator was operated over a range of flow settings. No one breathed from the ventilator.

4.7.1 DMOS Manned Run #1: During this test the horizontally oriented DMOS supplied oxygen to an Impact 754 ventilator. The goal was to assess performance of the DMOS when supplying an oxygen flow to a ventilator. The specific ventilator settings used are tabulated in Table 1. The 400 mL setting simulated a pediatric setting. The 600 mL setting was considered nominal. The higher settings of 1000 and 3000 mL were applied to test the DMOS at higher flows. The pararescuemen determined the flow settings. The altitude chamber was at Room Temperature. The participant operated the ventilator and breathed from the chamber oxygen system. No one was breathing from the ventilator. DMOS was tested at Ground Level and 15,000 feet. The data plot for Run #1 is at Appendix E, Figure E-1. At Ground Level the DMOS outlet pressure varied between 42 and 52 psig. At 15,000 feet the DMOS outlet pressure varied between 44 and 51 psig. The ventilator has a low pressure warning at 35 psig. The temperature of the oxygen at the ventilator inlet was close to ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaire is at Appendix F. The pararescueman indicated the ventilator operated normally.

4.7.2 DMOS Manned Run #2: The DMOS was operated at Ground Level; horizontal, vertical, and 45 degree orientations; and an ambient temperature of +130°F. Testing at altitude and +130°F was unwarranted and it would have posed additional risk for the participant. The participant wore a medical mask. Data plot for Run #2 is at Appendix E, Figure E-2. The blood oxygen saturation for the participant prior to the run was 97%. A flow setting of 15 LPM was used. The blood oxygen saturation of the participant rose to 98% when the DMOS was flowing oxygen at 15 LPM. DMOS supply pressure was about 50 psig. Mask oxygen temperature was about 10°F below the ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaire is at Appendix F. The participant indicated the system provided adequate flow. The participant also stated the oxygen temperature was unacceptable. The specific comment was "Temperature in my opinion not conducive to patient care." Based on Figure E-2, the mask temperature was 10°F

below the ambient temperature. Although the temperature was perceived as too hot, it was below the ambient temperature.

4.7.3 DMOS Manned Run #3: During this test the vertically oriented DMOS supplied oxygen to an Impact 754 ventilator (see Fig. 9). The goal was to assess performance of the vertical DMOS when supplying oxygen flow to a ventilator. The specific ventilator settings used are tabulated in Table 1. The 400 mL setting simulated a pediatric setting. The 600 mL setting was considered a nominal setting. The higher settings of 1000 mL and 3000 mL were applied to test the DMOS at higher flows. The altitude chamber was at Room Temperature. The participant operated the ventilator and breathed from the chamber oxygen system. No one was breathing from the ventilator. DMOS was tested at Ground Level and an altitude of 15,000 feet. The data plot for Run #3 is at Appendix E, Figure E-3. At Ground Level the DMOS outlet pressure varied between 42 and 52 psig. At 15,000 feet the DMOS outlet pressure varied between 44 and 51 psig. The ventilator has a low pressure warning at 35 psig. The temperature of the oxygen at the ventilator inlet was close to the ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaire is at Appendix F. The pararescueman indicated the ventilator operated normally. The pararescueman stated “Ventilator worked to specs.”



Figure 9. DMOS testing with ventilator in-progress

4.7.4 DMOS Manned Run #4: The DMOS was operated at Ground Level; horizontal, vertical, and 45 degree orientations; and an ambient temperature of -40°F. Testing at altitude and -40°F

was unwarranted and it would have posed additional risk for the participant. The participant wore a medical mask and cold weather gear. Data plot for Run #4 is at Appendix E, Figure E-4. The blood oxygen saturation for the participant prior to the run was 97%. A flow setting of 15 LPM was used. The blood oxygen saturation of the participant rose to 98% when the DMOS was flowing oxygen at 15 LPM. DMOS supply pressure was about 50 psig. Mask oxygen temperature was slightly warmer (2°F) than the ambient temperature. The battery percentage (BAT%) varied from 27% to 80%, although the liquid oxygen level (LOX%) appeared to function normally. The participant questionnaire is at Appendix F. The participant indicated the system provided adequate flow. The participant also stated the oxygen temperature “felt better than ambient air.”

4.7.5 DMOS Manned Run #5: During this test the 45 degree oriented DMOS supplied oxygen to an Impact 754 ventilator. The goal was to assess performance of the DMOS when supplying oxygen flow to the ventilator. The specific ventilator settings used are tabulated in Table 1. The 400 mL setting simulated a pediatric setting. The 600 mL setting was considered a nominal setting. The higher settings of 1000 mL and 3000 mL were applied to test the DMOS at higher flows. The altitude chamber was at Room Temperature. The participant operated the ventilator and breathed from the chamber oxygen system. No one was breathing from the ventilator. DMOS was tested at Ground Level and an altitude of 15,000 feet. The data plot for Run #5 is at Appendix E, Figure E-5. At Ground Level the DMOS outlet pressure varied between 42 and 53 psig. At 15,000 feet the DMOS outlet pressure varied between 43 and 51 psig. The ventilator has a low pressure warning at 35 psig. The temperature of the oxygen at the ventilator inlet was close to ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. The participant questionnaire is at Appendix F. The pararescueman indicated the ventilator operated normally. The pararescueman stated “Ventilator worked according to specs.”

4.7.6 DMOS Manned Run #6: This test investigated the performance of a horizontally oriented DMOS at Ground Level, 9,500 feet, and 15,000 feet (see Fig. 10). The goal was to ensure at each altitude the participant’s blood oxygen saturation was at or above their Ground Level blood oxygen saturation percentage. The chamber was at Room Temperature. The participant wore a standard medical mask. Data for Run #6 is at Appendix E, Figure E-6. The Ground Level blood oxygen saturation for the participant prior to the run was 97%. DMOS flows of 12 and 15 liters/minute were used. At Ground Level the participant’s blood oxygen saturation rose to 98% with a flow of 15 liters/minute. The blood oxygen saturation of the participant dropped to 89% at 9,500 feet when breathing air. At 15,000 feet the participant’s blood oxygen saturation was steady at 99% with flow settings of 15 liters/minute and 12 liters/minute. The instrumented mask’s oxygen concentration varied between about 26% and 94% at altitude. Standard medical masks have a poor facial seal, hence, wide variations in mask oxygen concentration can occur. DMOS supply pressure was about 48 psig. Mask oxygen temperature was close to ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. It was concluded flow settings of 12 LPM and 15 LPM provided sufficient oxygen to maintain Ground Level blood oxygen saturation at 15,000 feet. The participant questionnaires are at Appendix F. The participant indicated the system provided adequate flow and oxygen temperature was acceptable.



Figure 10. DMOS manned testing in-progress

4.7.7 DMOS Manned Run #7: This test investigated the performance of a vertically oriented DMOS at Ground Level, 9,500 feet, and 15,000 feet. The goal was to ensure at each altitude the participant's blood oxygen saturation remained at or above their Ground Level blood oxygen saturation percentage. The chamber was at Room Temperature. The participant wore a standard medical mask. Data run for Run #7 is at Appendix E, Figure E-7. The Ground Level blood oxygen saturation for the participant prior to the run was 98%. DMOS flows of 12 and 15 liters/minute were used. At Ground Level the participant's blood oxygen saturation rose to 99% with a flow of 15 liters/minute. The blood oxygen saturation of the participant dropped to 90% at 9,500 feet when breathing air. At 15,000 feet the participant's blood oxygen saturation was steady at 98% at flow settings of 15 liters/minute and 12 liters/minute. The instrumented mask's oxygen concentration varied between about 89% and 94% during the altitude run. The mask must have had a tight seal and the participant must have been breathing at a low rate. DMOS supply pressure was about 48 psig. Mask oxygen temperature was close to ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally during the run. It was concluded flow settings of 12 LPM and 15 LPM provided sufficient oxygen to maintain Ground Level blood oxygen saturation at 15,000 feet. The participant questionnaire is at Appendix F. The participant indicated the system provided adequate flow and oxygen temperature was acceptable.

4.7.8 DMOS Manned Run #8: This test investigated the performance of a 45 degree oriented DMOS at Ground Level, 9,500 feet, and 15,000 feet. The goal was to ensure at each altitude the participant's blood oxygen saturation remained at or above their Ground Level blood oxygen

saturation percentage. The chamber was at Room Temperature. The participant wore a standard medical mask. Data run for Run #8 is at Appendix E, Figure E-8. The Ground Level blood oxygen saturation for the participant prior to the run was 96%. DMOS flows of 12 and 15 liters/minute were used. At Ground Level the participant's blood oxygen saturation rose to 98% with a flow of 15 liters/minute. The blood oxygen saturation of the participant dropped to 89% at 9,500 feet when breathing air. At 15,000 feet the participant's blood oxygen saturation was steady at 98% with flow settings of 15 liters/minute and 12 liters/minute. The instrumented mask's oxygen concentration varied between about 57% and 94% during the altitude run. DMOS supply pressure was about 48 psig. Mask oxygen temperature was about ambient temperature. The battery life percentage (BAT%) and liquid oxygen level (LOX%) appeared to function normally. It was concluded flow settings of 12 LPM and 15 LPM provided sufficient oxygen to maintain Ground Level blood oxygen saturation at 15,000 feet. The participant questionnaire is at Appendix F. The participant indicated the system provided adequate flow and oxygen temperature was acceptable.

4.8 DMOS Manned Testing Pass/Fail Criteria Results.

4.8.1 Success Criterion #1: OGS oxygen samples shall comply with 93% Oxygen USP standard.

PASS - Analysis showed the OGS oxygen samples passed the 93% USP oxygen standard (See Appendix G; Lab Reports 2012LA40749001, 2012LA40907001, 2012LA41088001, and 2012LA41088002).

4.8.2 Success Criterion #2: Temperature of oxygen delivered to mask shall not be greater than 20°F below chamber temperature.

PASS – Mask temperatures were less than 20°F below chamber temperature.

4.8.3 Success Criterion #3: Blood oxygen saturation shall be $\geq 95\%$.

PASS – Blood oxygen saturation was greater than 95% when oxygen flows of 12 liters/minute and 15 liters/minute were used.

4.8.4 Success Criterion #4: DMOS shall interface properly to Impact 754 ventilator, supply pressure of 50 ± 5 psig shall be maintained, and ventilator oxygen delivery temperature shall not be greater than 20°F below ambient chamber temperature.

FAIL – The DMOS interfaced properly to the Impact 754 ventilator. The supply pressure did drop below 50 ± 5 psig. The lowest pressure observed was 42 psig. The ventilator oxygen delivery temperature was not greater than 20°F below ambient chamber temperature.

Note: Although the lowest pressure observed was 42 psig, the Impact 754 ventilator has a low pressure warning at 35 psig. Because the lowest DMOS delivery pressure was above the ventilator pressure warning set point, the performance of the DMOS was deemed acceptable.

4.8.5 Success Criterion #5: Impact 754 ventilator shall operate normally at Ground Level, 15,000 feet, and during ascent and descent.

PASS – The Impact 754 ventilator operated normally at Ground Level, 15,000 feet, and during ascent and descent.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 MMOS: Safe-to-fly testing was accomplished on the Guardian Angel Mounted Medical Oxygen System (MMOS) (Essex Cryogenics, Inc., St. Louis MO, P/N 19052-50C-0105-1, S/N P1010 and P1011). MMOS was tested in unmanned and manned configurations; and at ambient temperatures of Room Temperature, +130°F, and -40°F. Pararescuemen participated in the manned testing. The system was filled with 93% Oxygen USP liquid generated by a pre-production Guardian Angel Oxygen Generating System (OGS). MMOS was found safe-to-fly using the configurations and conditions noted below.

a. MMOS was safe up to a cabin altitude of 15,000 feet with up to two patients wearing medical masks. MMOS should only be used in the following orientations: upright horizontal position and upright vertical position. At cabin altitudes between 10,000 feet and 15,000 feet the oxygen flow selectors should be set to 12 LPM or greater. This flow selector setting was necessary to maintain Ground Level blood oxygen saturation. Configuration components are noted below.

(1) MMOS.

(2) Seven (7) feet of plastic tubing from MMOS barbed connector to each medical mask.

(3) Up to two medical masks.

b. MMOS was safe up to a cabin altitude of 15,000 feet while supplying oxygen to one Impact 754 ventilator. MMOS should only be used in the following orientations: upright horizontal position and upright vertical position. At nominal ventilator tidal volume and breaths/minute settings and non-dilution mode the MMOS delivery pressure was at or above 45 psig. At high ventilator tidal volume and breaths/minute settings MMOS appeared to deliver adequate flow but the supply pressure occasionally dropped to 39 psig. The ventilator pressure warning did not alarm because its set point is 35 psig. Configuration components are noted below.

(1) MMOS.

(2) One standard DISS medical oxygen hose from the MMOS DISS outlet to the ventilator.

(3) One Impact 754 ventilator.

c. MMOS must be filled with oxygen conforming to 93% Oxygen USP liquid or Aviators' Breathing Oxygen liquid conforming to MIL-PRF-27210H.

d. MMOS should only be used with patients after it receives Food and Drug Administration (FDA) approval.

e. Recommendations:

(1) The LOX Quantity (%) indicator malfunctioned on MMOS (S/N P1010) during the testing. The indicator on MMOS (S/N P1011) was reported within tolerances. Recommend the user periodically check the LOX Quantity (%) indicator for proper operation.

(2) One time during operation at an ambient temperature of -40°F the LOX Quantity (%) display did not illuminate for several seconds after depressing the BATT/QTY button. Upon a second button depression the display worked. Recommend the user is informed this condition might occur when operating at extremely low ambient temperatures.

(3) During operation at -40°F the BATT Life (%) gave very low values and sometimes read 0%. The LOX Quantity (%) appeared to work properly, except the one time noted above. Recommend the user is informed this condition might occur when operating at extremely low ambient temperatures.

(4) During operation at -40°F the rebreather bags on the medical masks split and leaked oxygen. The masks used are considered standard issue for pararescue personnel. MMOS continued to deliver oxygen, however, an unsafe condition might occur if the mask rebreather bags split while flying above 10,000 feet. Recommend the user be informed these rebreather type medical masks may not be suitable for use at extremely low ambient temperatures and, if they are used at low temperatures, the user should periodically check the mask for rebreather bag cracks.

f. Findings:

(1) The BATT Life (%) appeared to fluctuate during the testing, although the LOX Quantity (%) functioned properly. Suggest any future upgrades change percentage to a color code for battery condition (for example, green, yellow, and red). During testing the users commented the color code approach would be more user-friendly.

(2) MMOS was exposed to rapid decompressions from 8,000 feet to 40,000 feet during the unmanned testing. MMOS continued to function properly during and after the decompression, during descent, after returning to 8,000 feet, and upon return to Ground Level.

5.2 DMOS: Safe-to-fly testing was conducted on the portable Guardian Angel Dismounted Medical Oxygen System (DMOS) (Essex Cryogenics, Inc., St. Louis MO, P/N 19062-50C-0106-1, S/N P1005, P1006, P1009, and P1010). DMOS was tested in the unmanned and manned configurations; and ambient temperatures of Room Temperature, +130°F, and -40°F. Pararescuemen participated in the manned testing. The system was filled with 93% Oxygen USP liquid generated by the Guardian Angel Oxygen Generating System (OGS). DMOS was found safe-to-fly using the configurations and conditions noted below.

a. DMOS is safe up to a cabin altitude of 15,000 feet with one patient breathing from a standard medical mask. DMOS should only be used in the following orientations: upright horizontal position, upright vertical position, and any angle between upright horizontal and upright vertical. Use in other orientations could result in oxygen flow and pressure deficiencies. At cabin altitudes between 10,000 feet and 15,000 feet the oxygen flow selector should be set to 12 liters/minute or greater. This flow selector setting is needed to maintain Ground Level blood oxygen saturation. Configuration components are noted below.

- (1) DMOS.
- (2) Seven feet of plastic tubing from DMOS barbed connector labeled "PATIENT" to the medical mask.
- (3) One standard medical mask.

b. DMOS is safe up to a cabin altitude of 15,000 feet while supplying oxygen to one Impact 754 ventilator. DMOS should only be used in the following orientations: upright horizontal position, upright vertical position, and any angle between upright horizontal and upright vertical. At nominal ventilator tidal volume and breaths/minute settings and non-dilution mode the DMOS delivery pressure was at or above 45 pounds/square inch gauge (psig). At high ventilator tidal volume and breaths/minute settings DMOS appeared to deliver adequate flow but the supply pressure occasionally dropped to 42 psig. The ventilator pressure warning did not alarm because its set point is 35 psig. Configuration components are noted below.

- (1) DMOS.
- (2) One standard Diameter Index Safety System (DISS)-to-DISS medical oxygen hose from the DMOS "AUX." outlet to the ventilator inlet connection.
- (3) One Impact 754 ventilator.

c. Very limited testing was conducted utilizing the DMOS "PARACHUTIST" outlet port and a Phantom oxygen mask. The "PARACHUTIST" port is not authorized for parachuting operations.

d. DMOS must be filled with oxygen conforming to 93% Oxygen U.S. Pharmacopeia (USP) liquid or Aviators' Breathing Oxygen liquid conforming to MIL-PRF-27210H.

e. DMOS should only be used with patients after it receives Food and Drug Administration (FDA) approval.

f. Recommendation: During operation at -40°F the Battery Life Remaining (%) fluctuated. The LOX Remaining (%) appeared to work properly. Recommend the user is informed the Battery Life Remaining (%) may fluctuate at extremely low ambient temperatures.

g. Finding: DMOS was exposed to 7 second decompressions from 8,000 feet to 40,000 feet during the unmanned testing. DMOS continued to function properly during and after the decompression, during descent, after returning to 8,000 feet, and upon return to Ground Level.

5.3 OGS:

a. The oxygen used to fill the MMOS and DMOS was supplied by an Essex Cryogenics, pre-production Oxygen Generating System (OGS). The OGS oxygen was sampled and analyzed several times during the test effort. The OGS oxygen complied with the 93% Oxygen USP standard. Recommend the user periodically check the oxygen supplied by the OGS to ensure compliance to the 93% Oxygen USP standard.

b. A non-operating and empty OGS was exposed to a 7 second decompression from 8,000 feet to 40,000 feet. After the decompression the device functioned normally when operated at Ground Level.

APPENDIX A: MMOS Unmanned Data

Figure A-1. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; Room Temp; Horizontal; 8 LPM
Setting

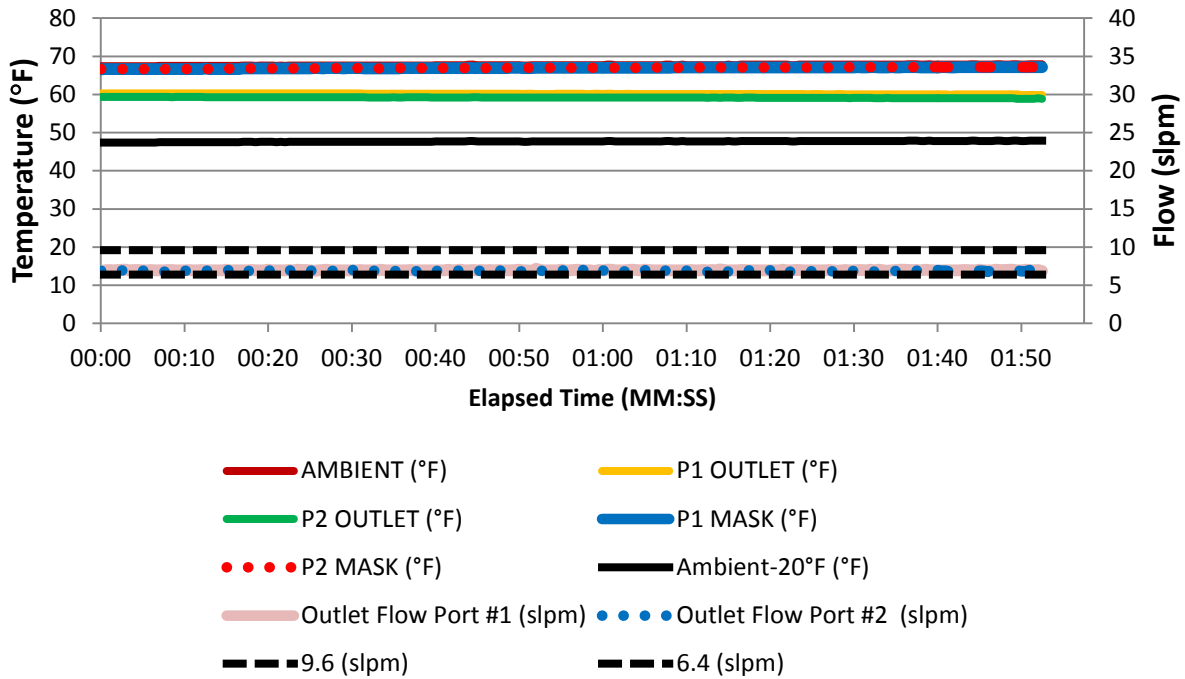


Figure A-2. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; Room Temp; Horizontal; 8 LPM Setting

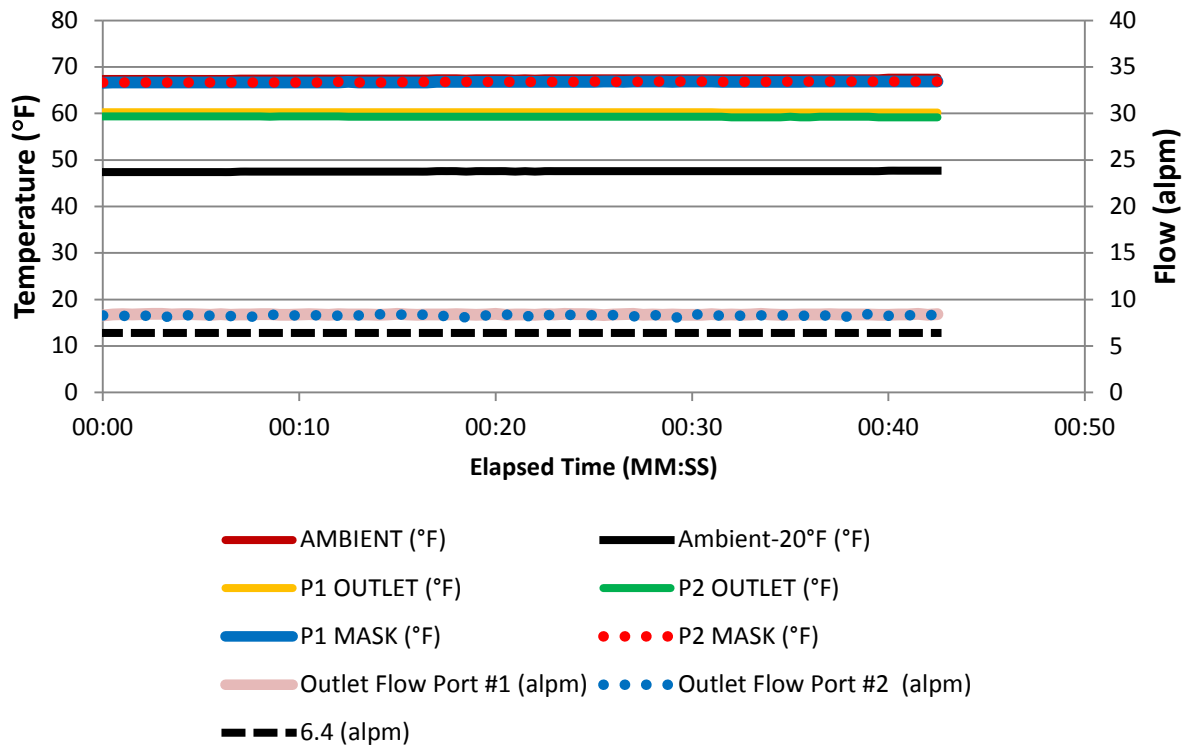


Figure A-3. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; Room Temp; Horizontal; 8 LPM Setting

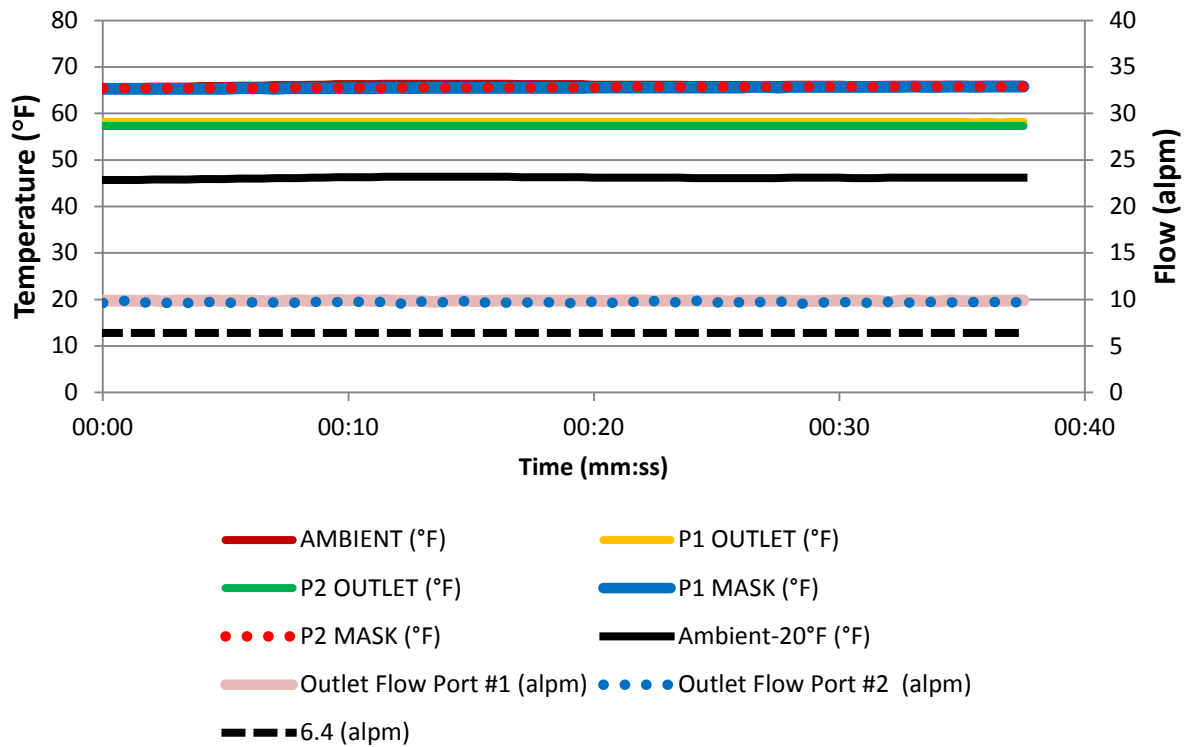


Figure A-4. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; Room Temp; Horizontal; 8 LPM Setting

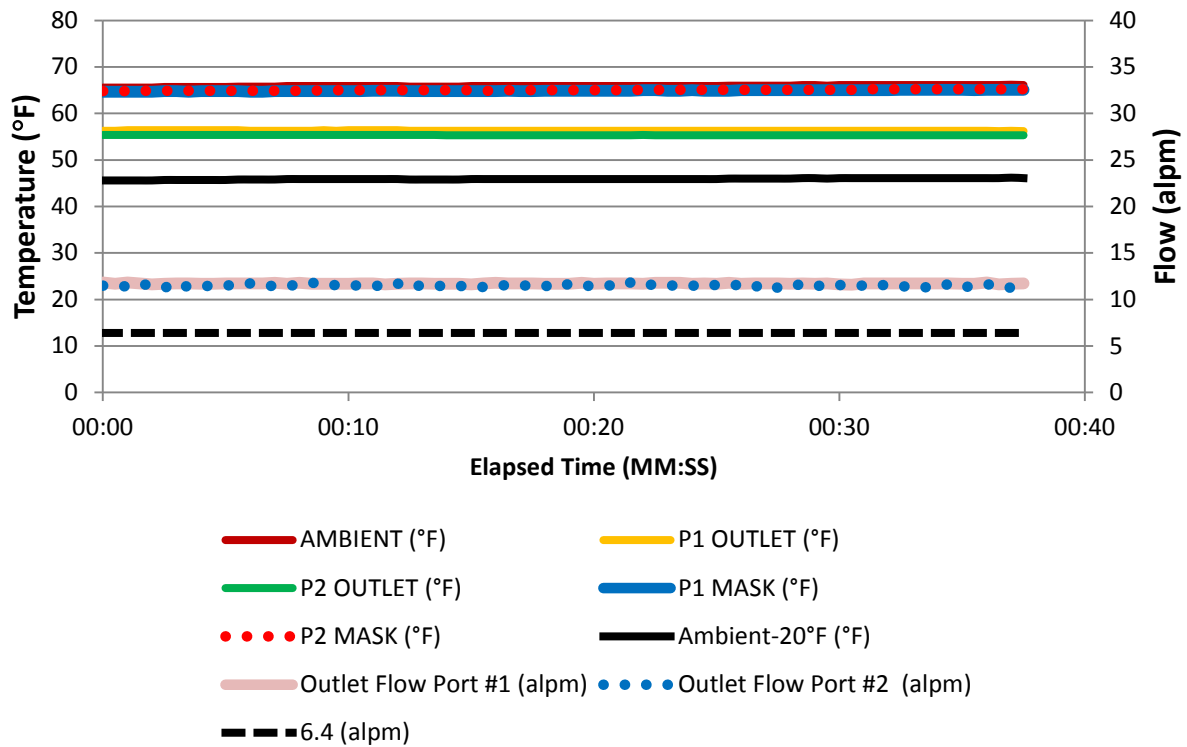


Figure A-5. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; Room Temp; Horizontal; 15 LPM
Setting

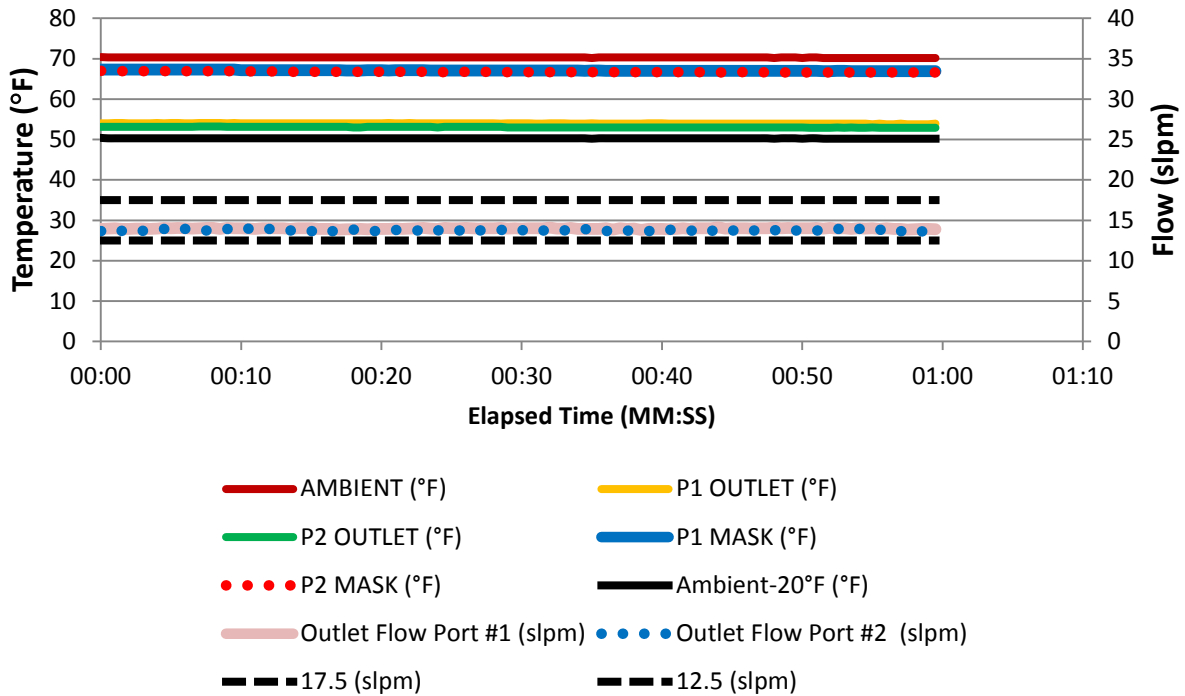


Figure A-6. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; Room Temp; Horizontal; 15 LPM Setting

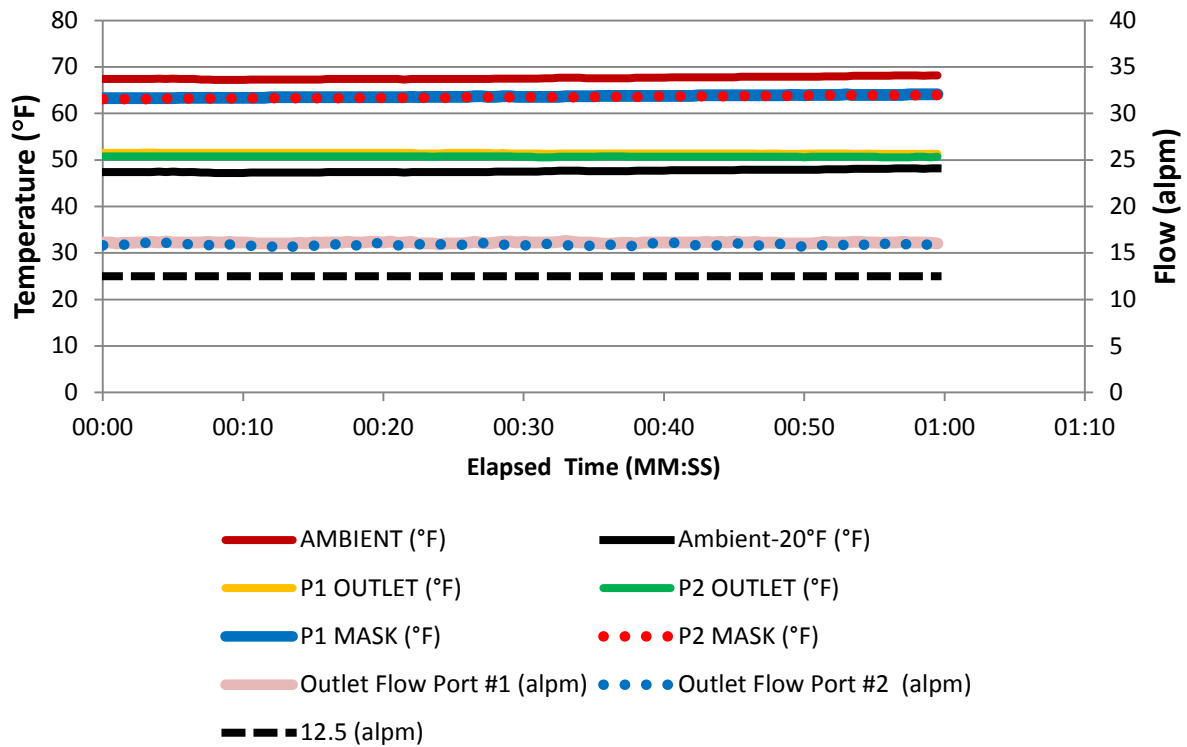


Figure A-7. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; Room Temp; Horizontal; 15 LPM
Setting

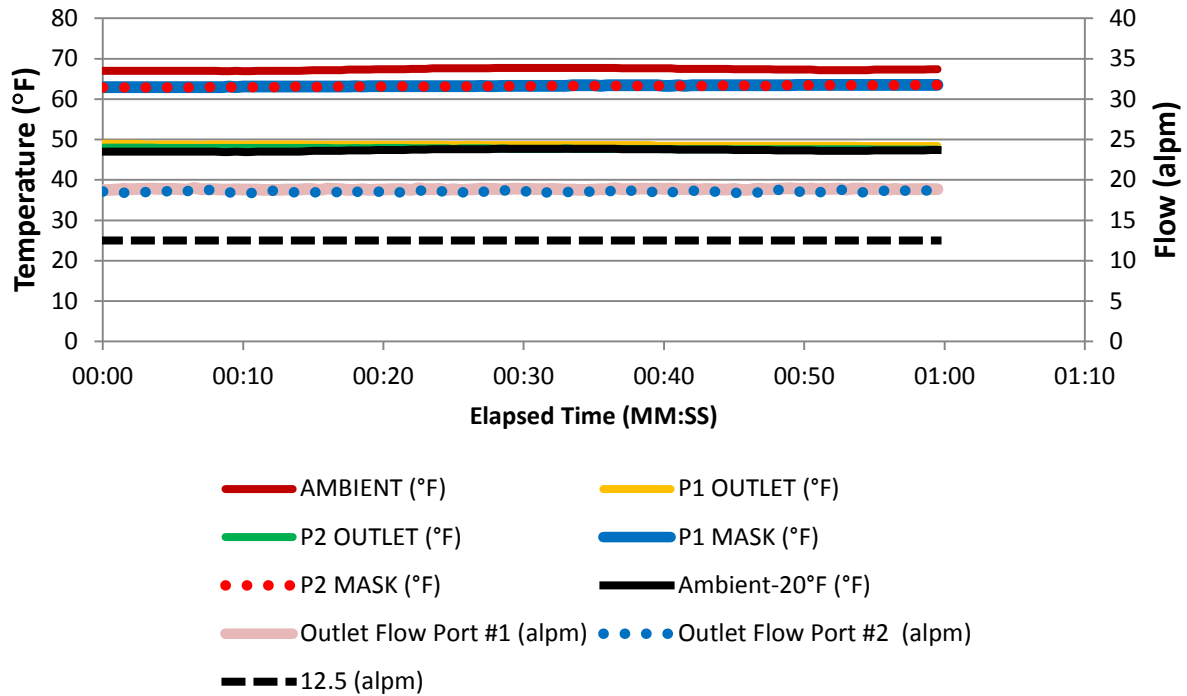


Figure A-8. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; Room Temp; Horizontal; 15 LPM
Setting

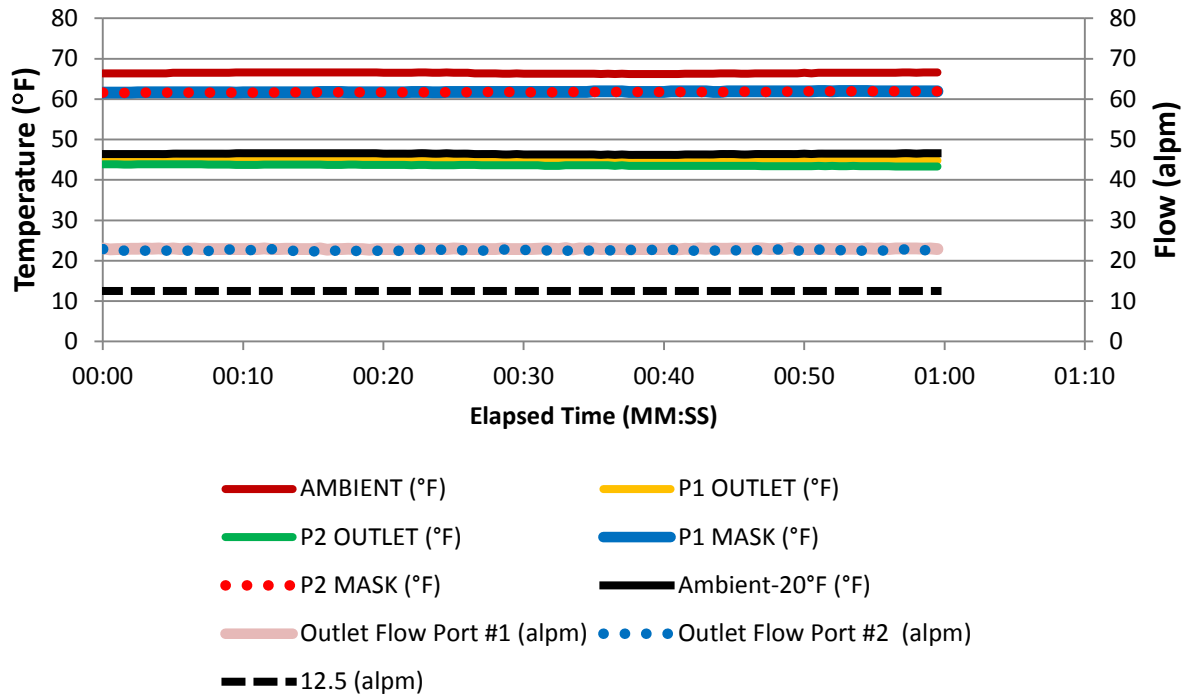


Figure A-9. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; Room Temp; Vertical; 8 LPM
Setting

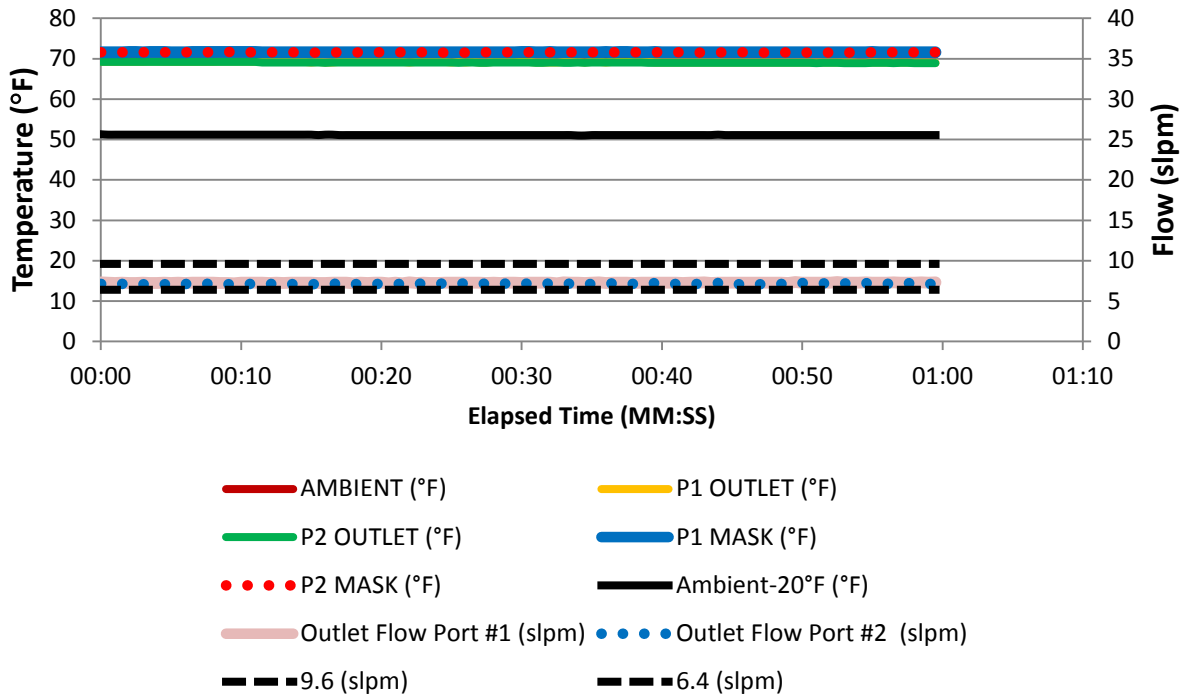


Figure A-10. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; Room Temp; Vertical; 8 LPM Setting

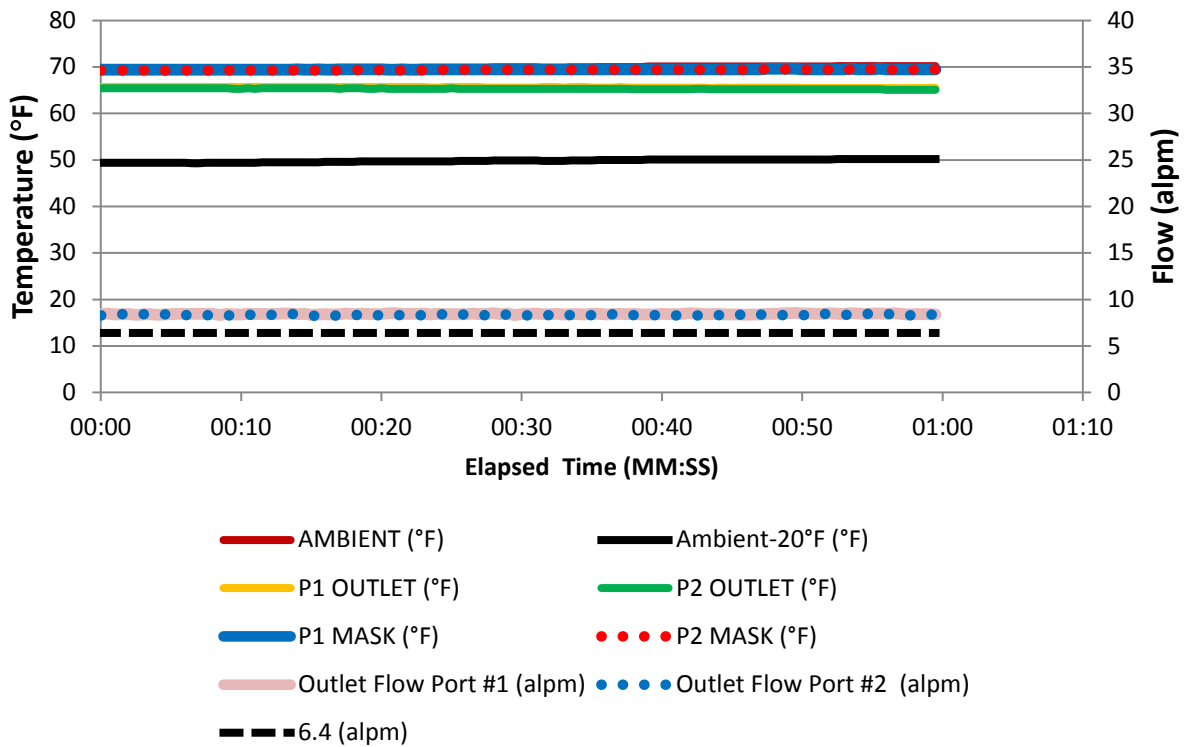


Figure A-11. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; Room Temp; Vertical; 8 LPM Setting

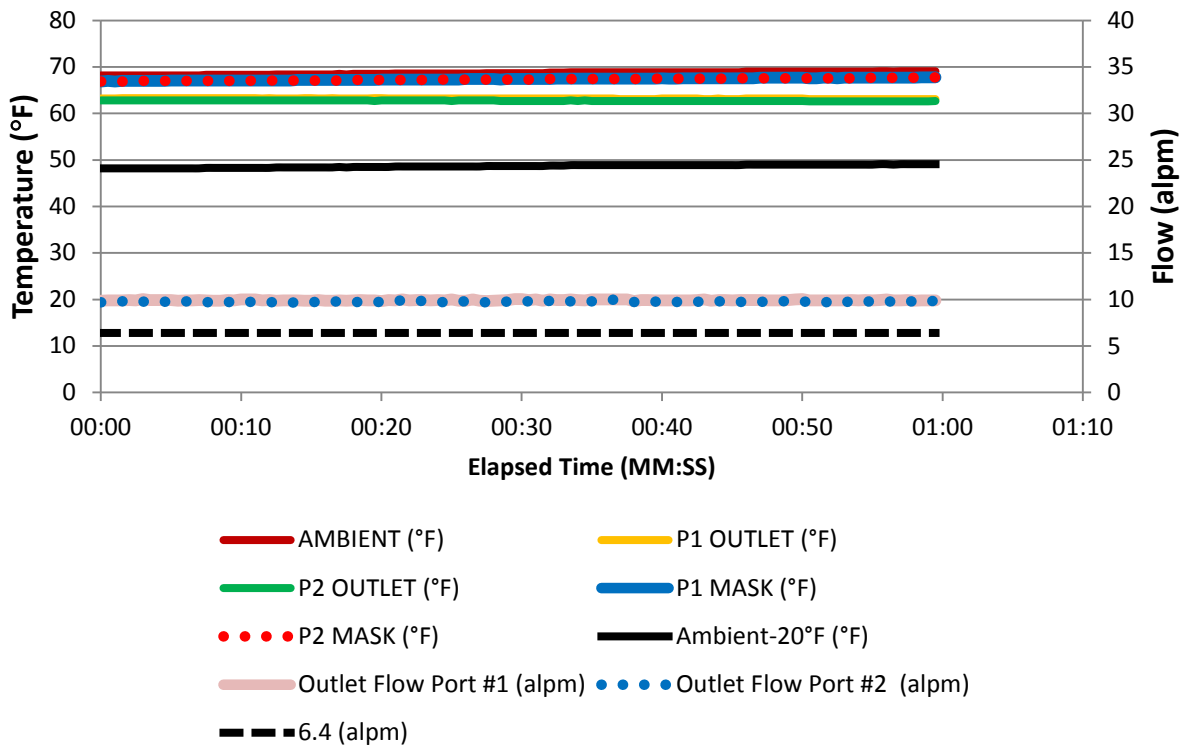


Figure A-12. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; Room Temp; Vertical; 8 LPM Setting

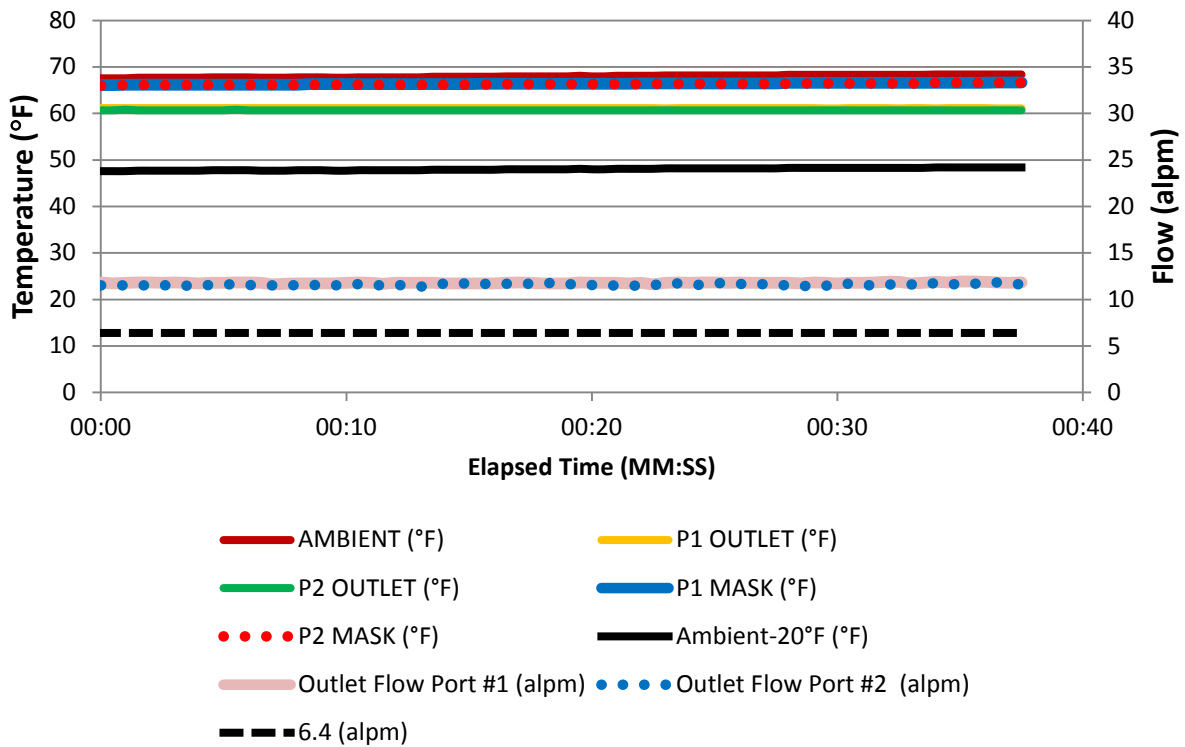


Figure A-13. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; Room Temp; Vertical; 15 LPM
Setting

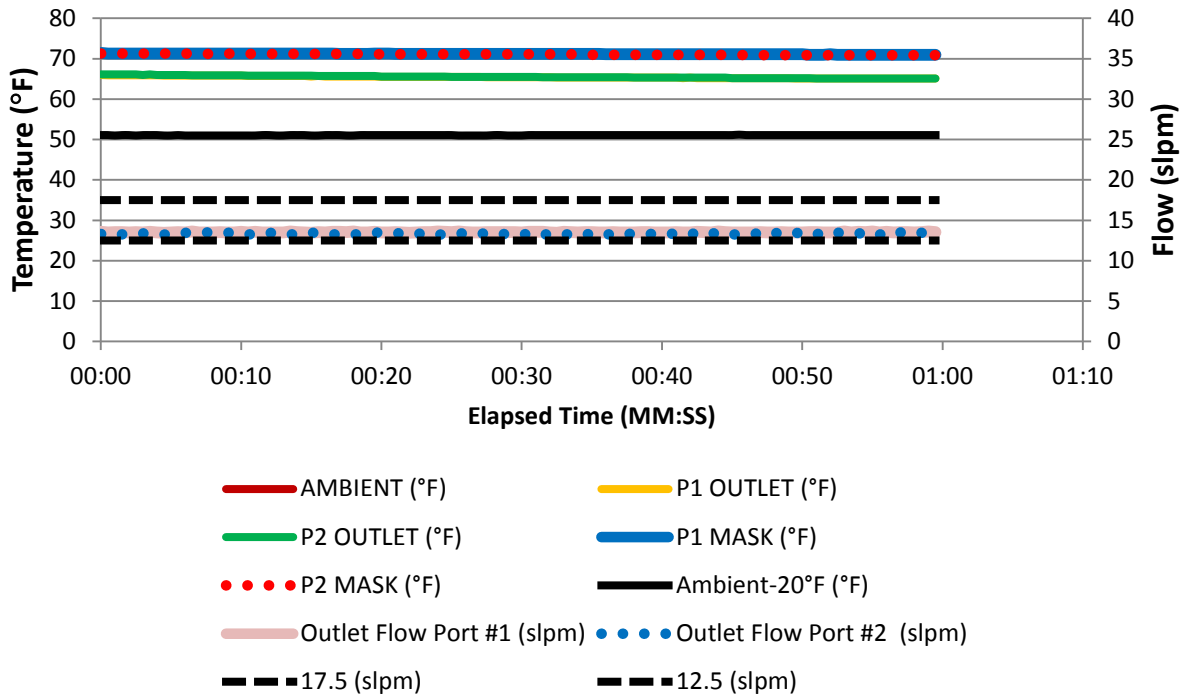


Figure A-14. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; Room Temp; Vertical; 15 LPM Setting

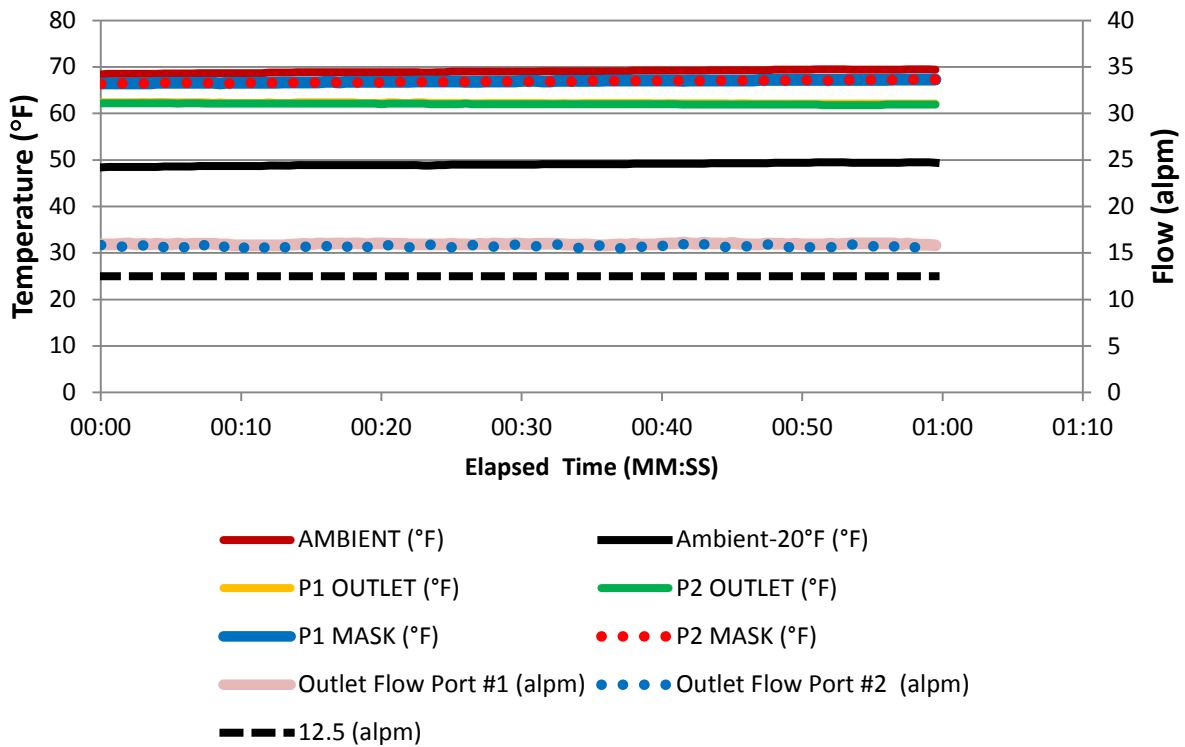


Figure A-15. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; Room Temp; Vertical; 15 LPM Setting

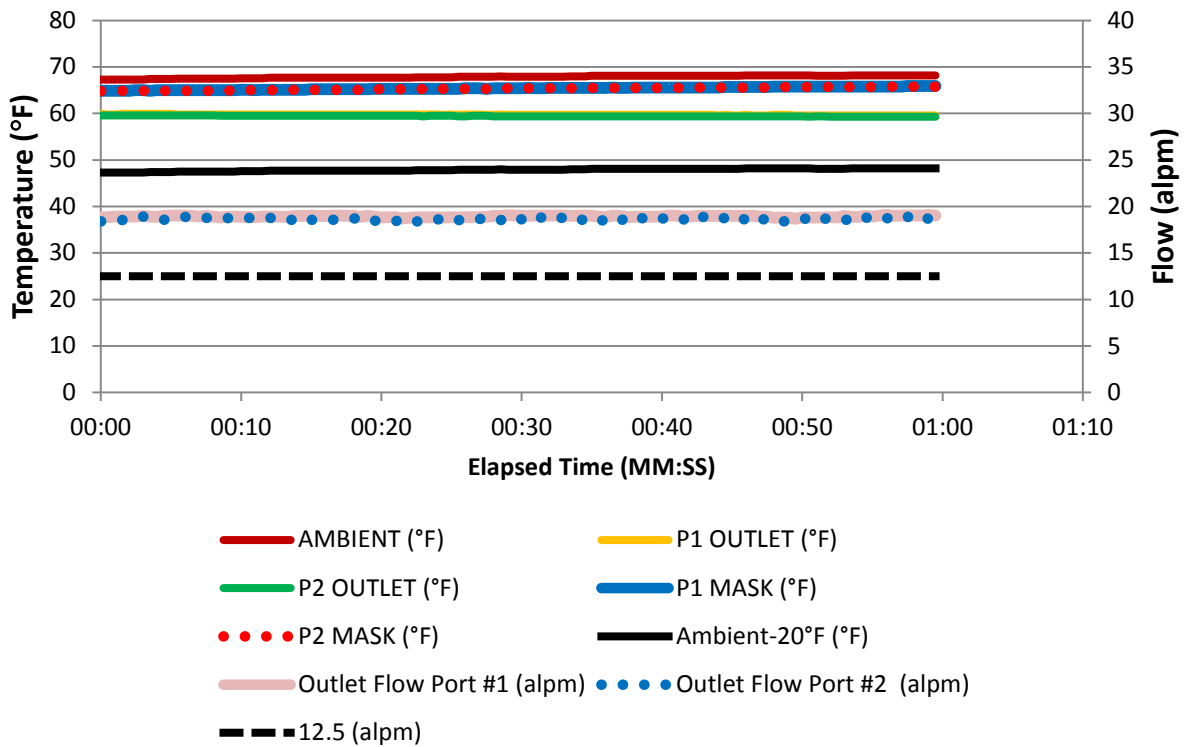


Figure A-16. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; Room Temp; Vertical; 15 LPM Setting

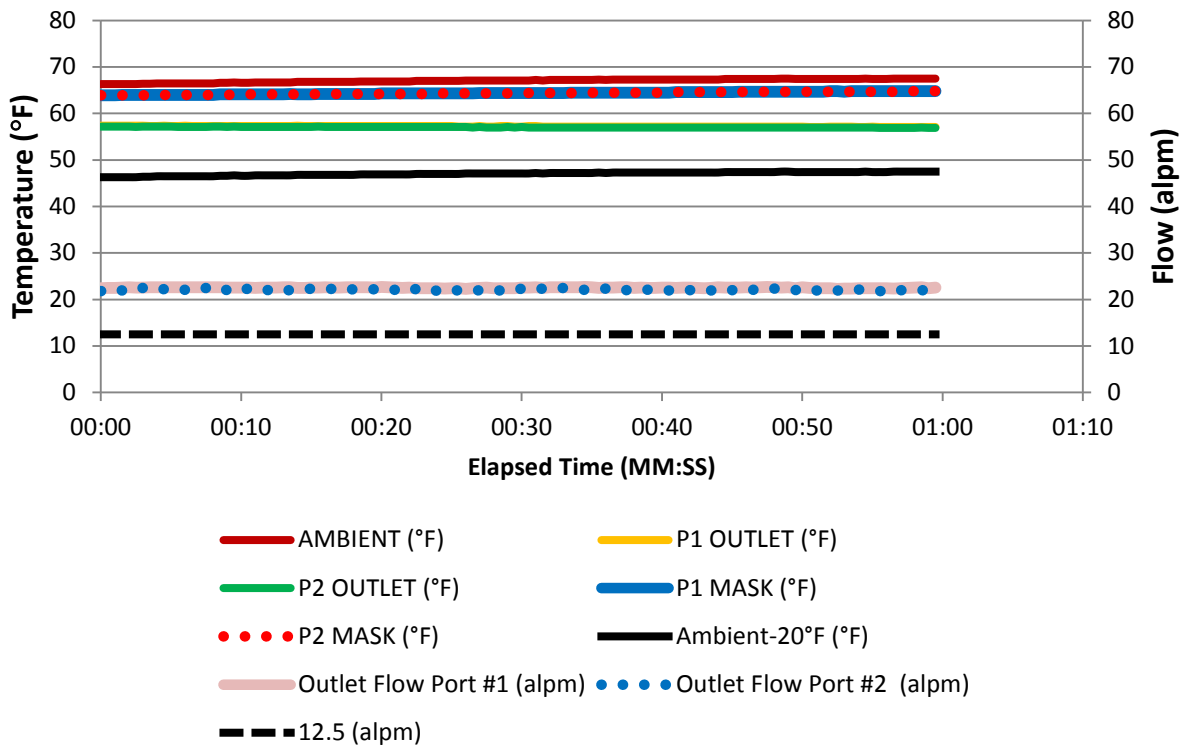


Figure A-17. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; +130°F; Horizontal; 8 LPM
Setting

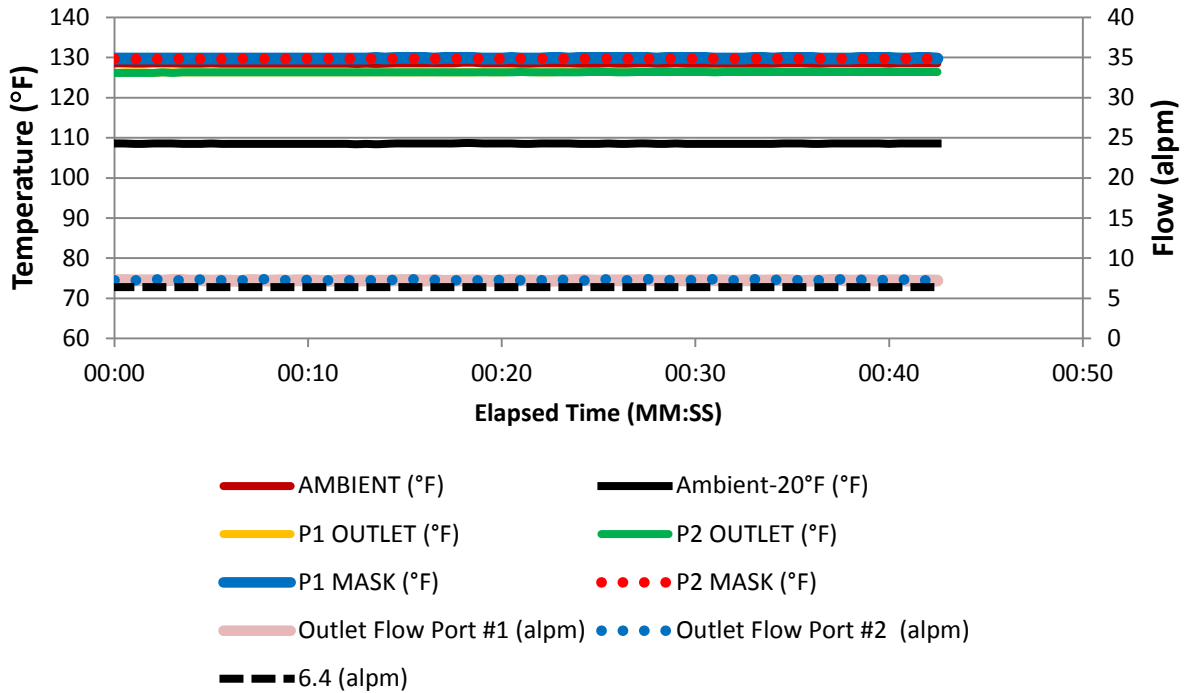


Figure A-18. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; +130°F; Horizontal; 8 LPM Setting

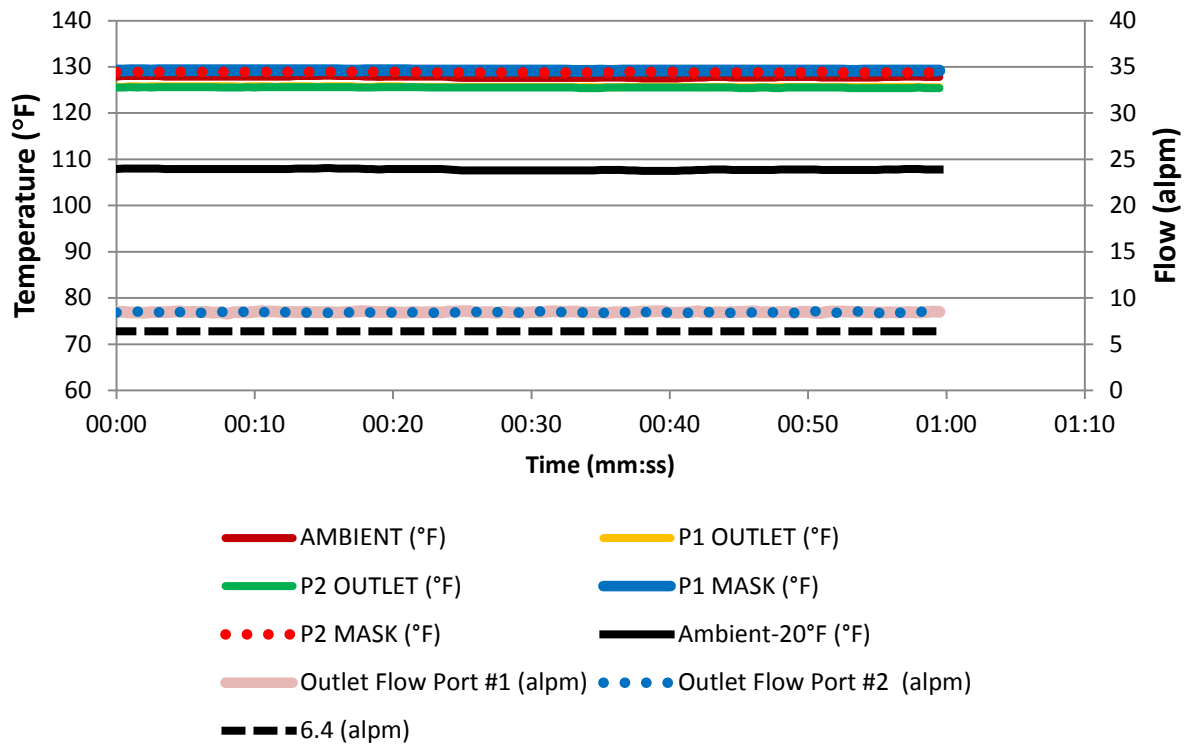


Figure A-19. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; +130°F; Horizontal; 8 LPM Setting

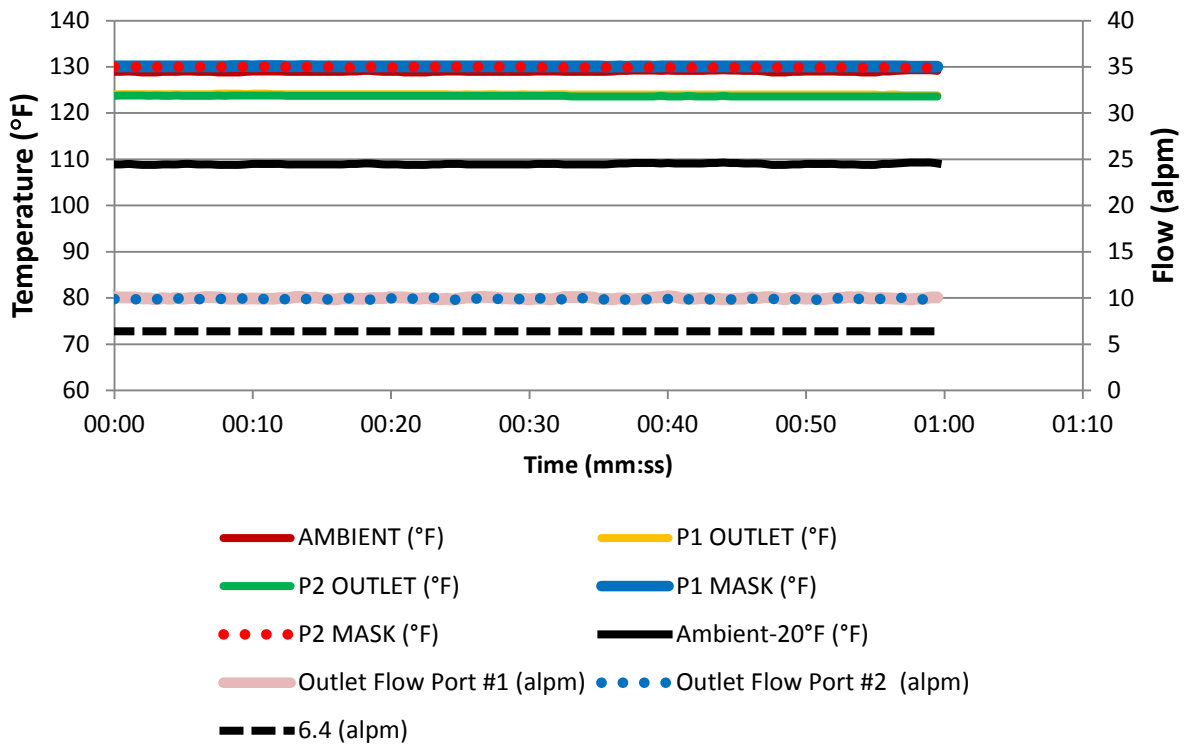


Figure A-20. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; +130°F; Horizontal; 8 LPM Setting

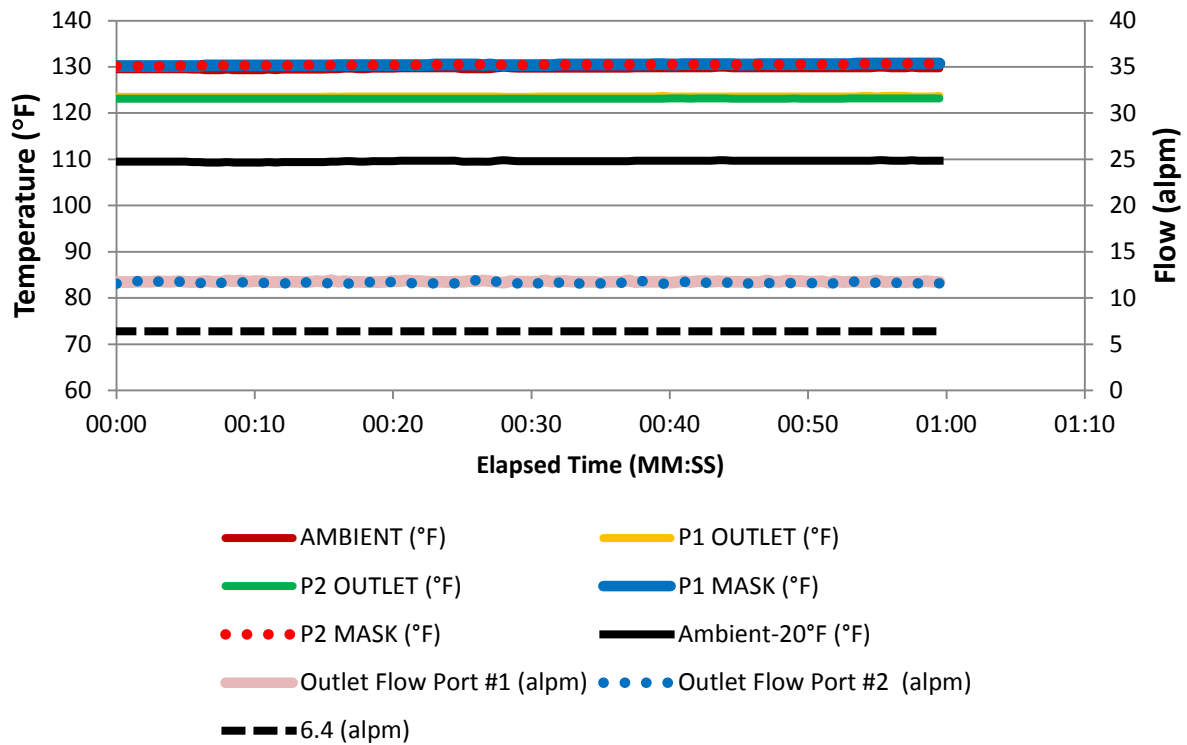


Figure A-21. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; +130°F; Horizontal; 15 LPM
Setting

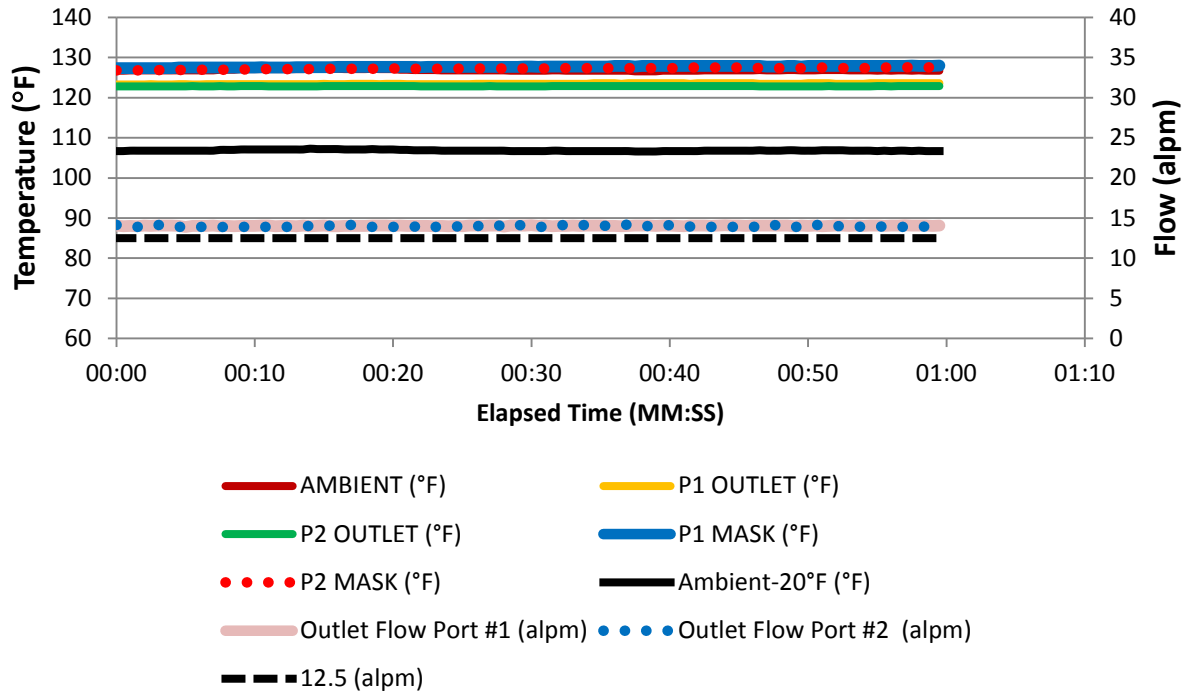


Figure A-22. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; +130°F; Horizontal; 15 LPM Setting

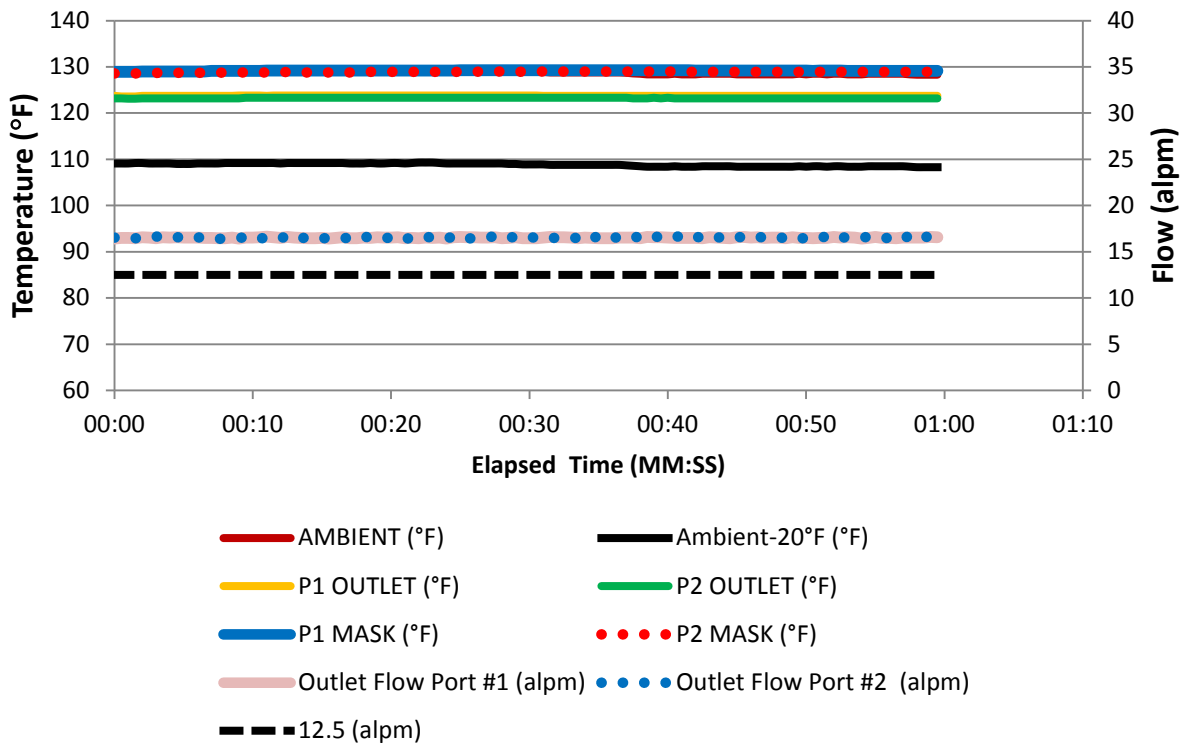


Figure A-23. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; +130°F; Horizontal; 15 LPM Setting

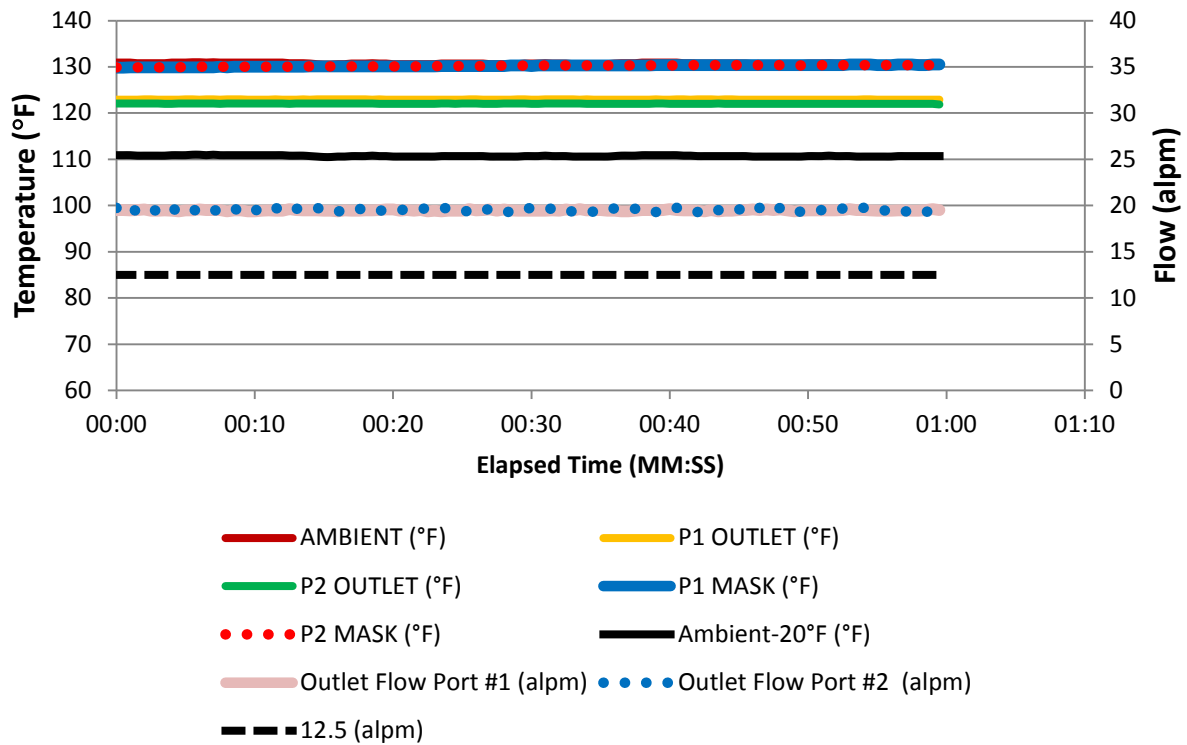


Figure A-24. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; +130°F; Horizontal; 15 LPM Setting

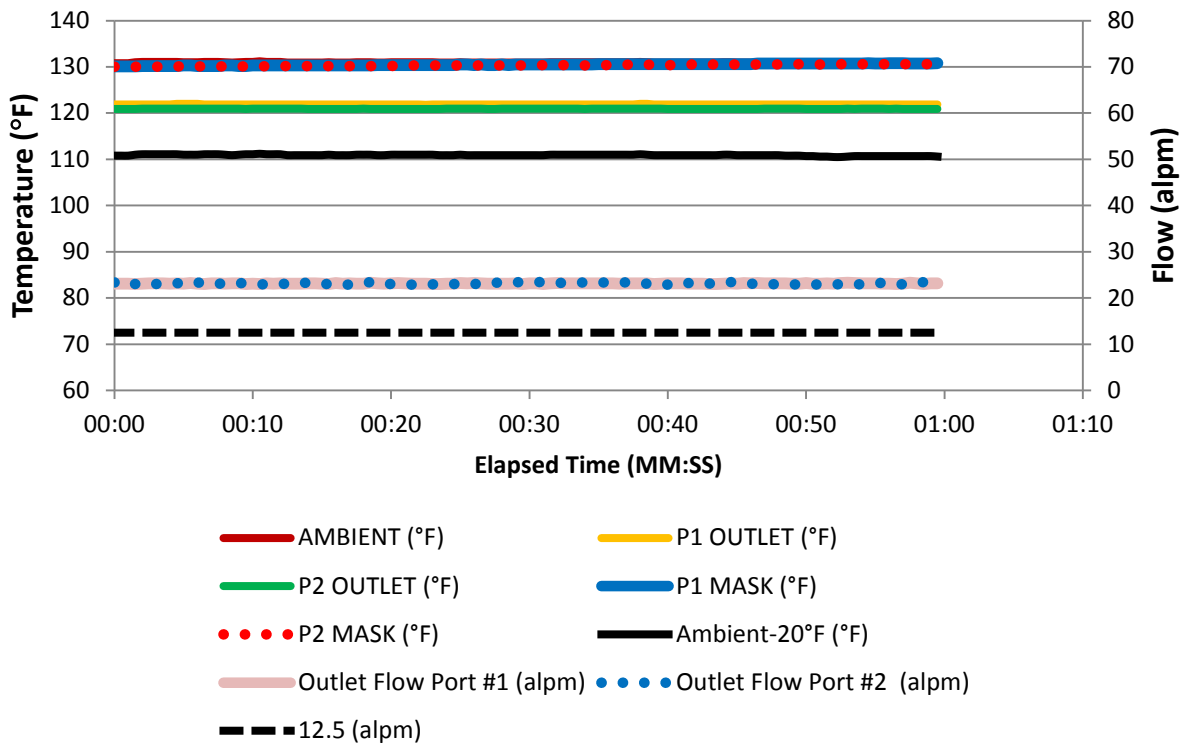


Figure A-25. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; +130°F; Vertical; 8 LPM Setting

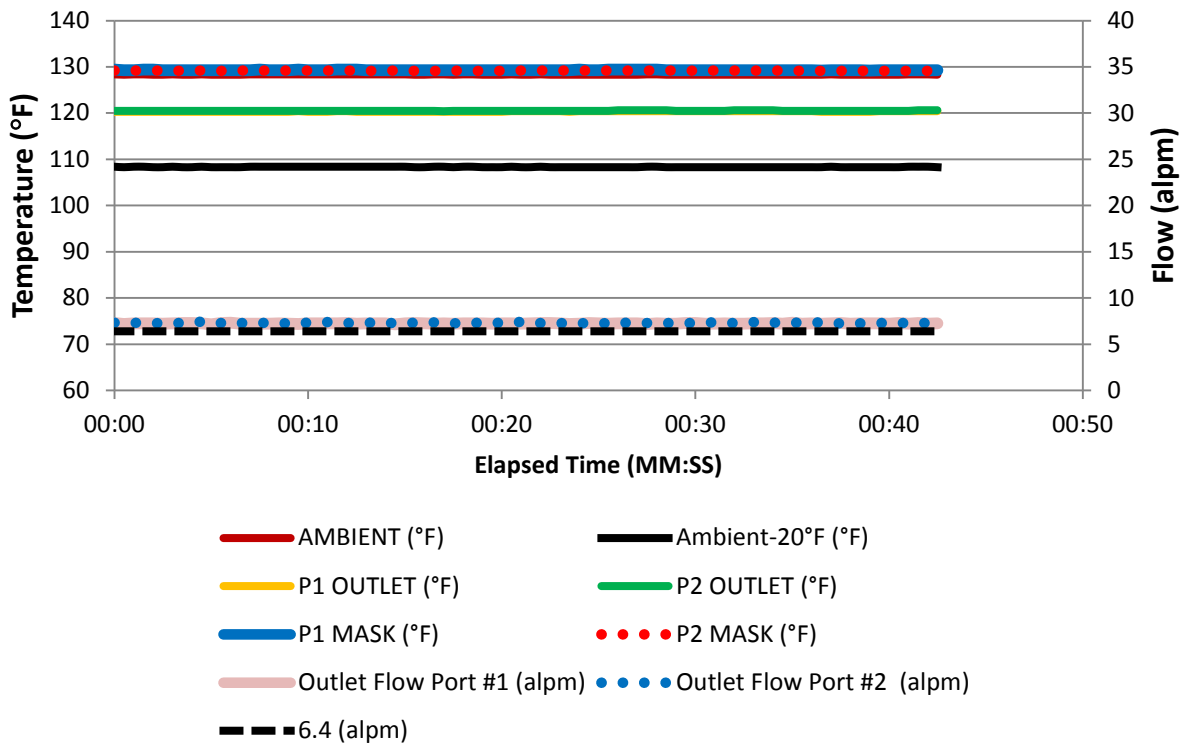


Figure A-26. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; +130°F; Vertical; 8 LPM Setting

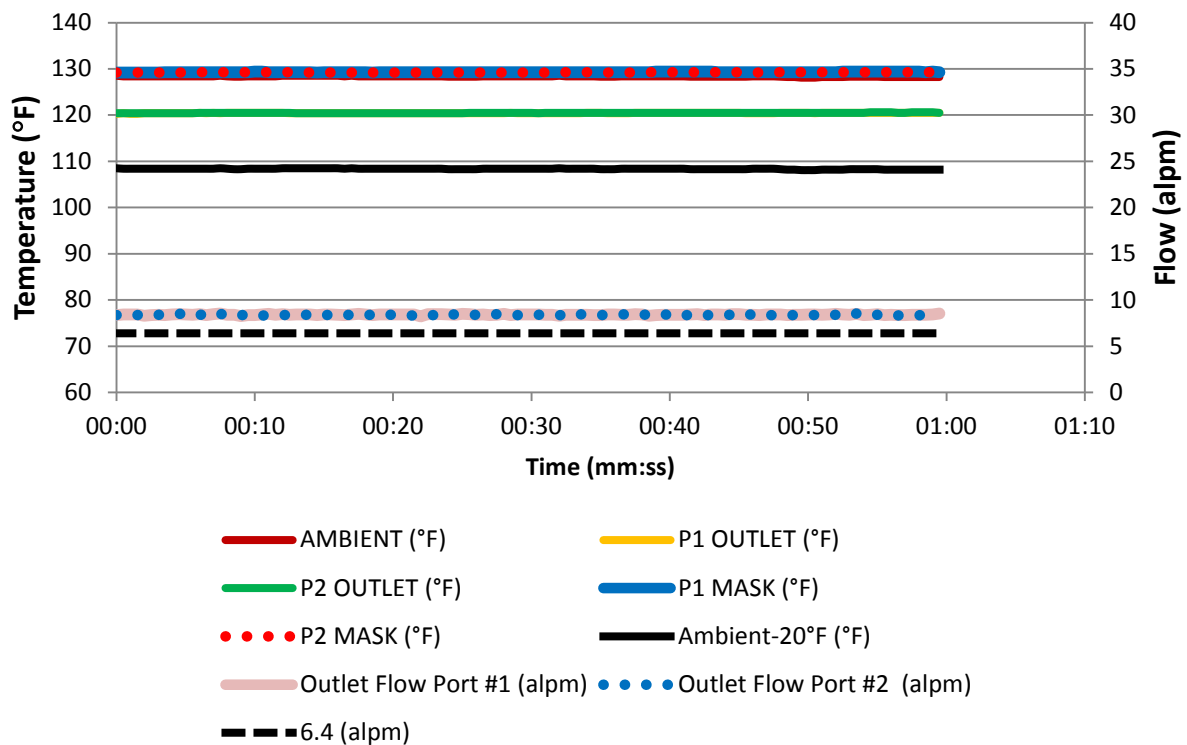


Figure A-27. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; +130°F; Vertical; 8 LPM Setting

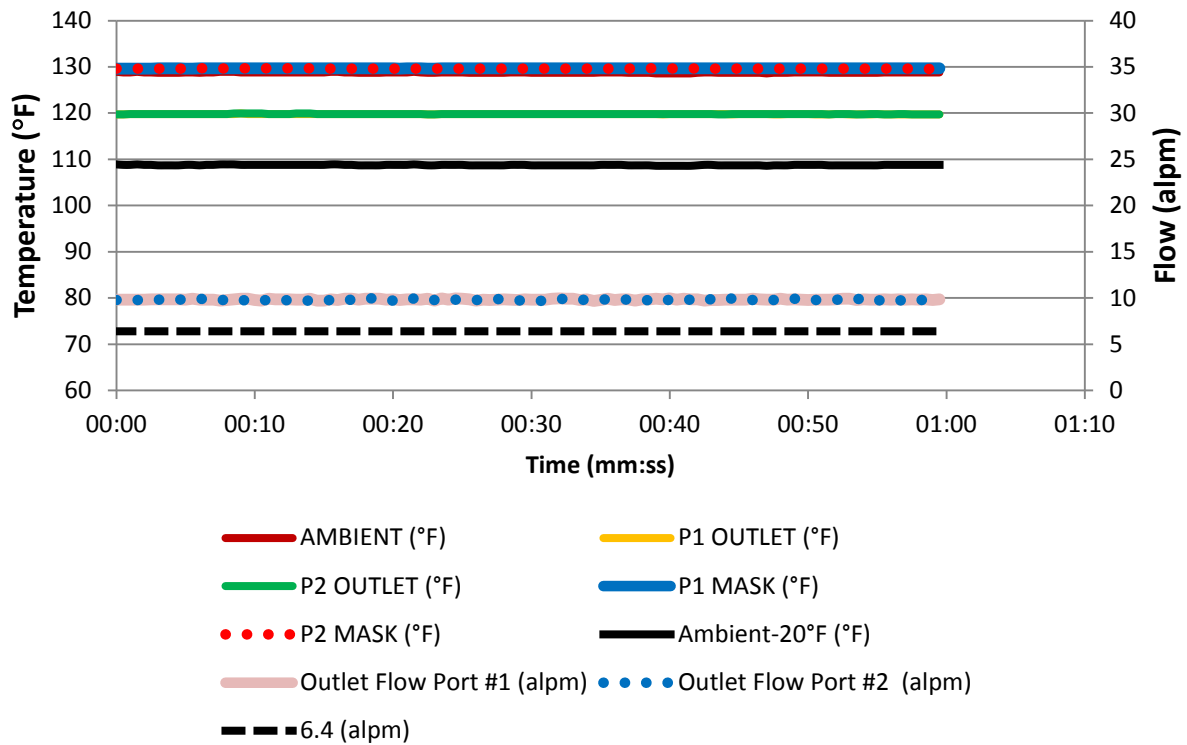


Figure A-28. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; +130°F; Vertical; 8 LPM Setting

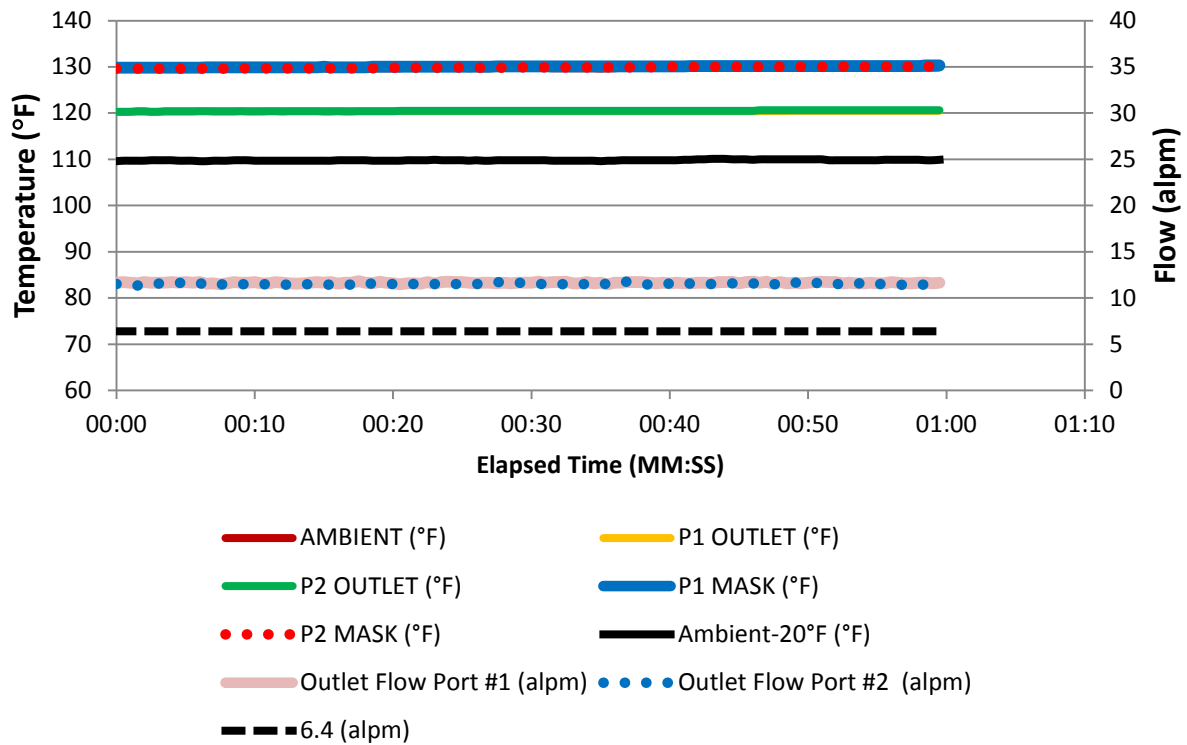


Figure A-29. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; +130°F; Vertical; 15 LPM Setting

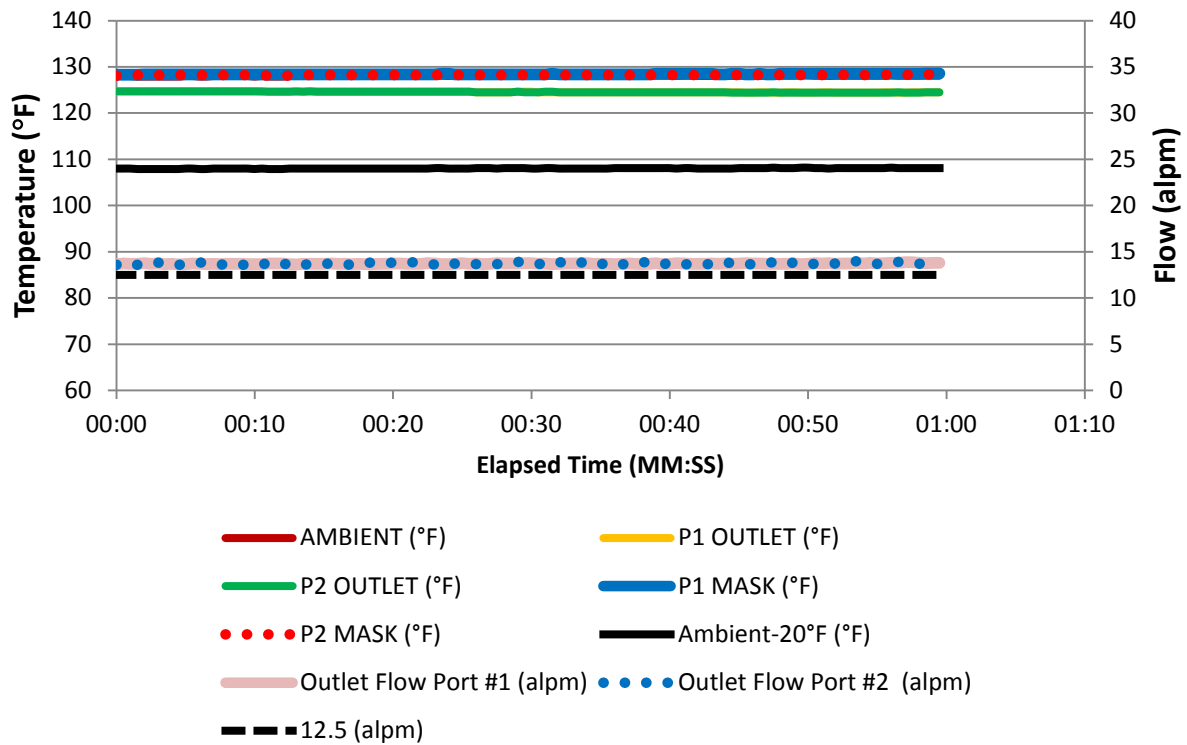


Figure A-30. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; +130°F; Vertical; 15 LPM Setting

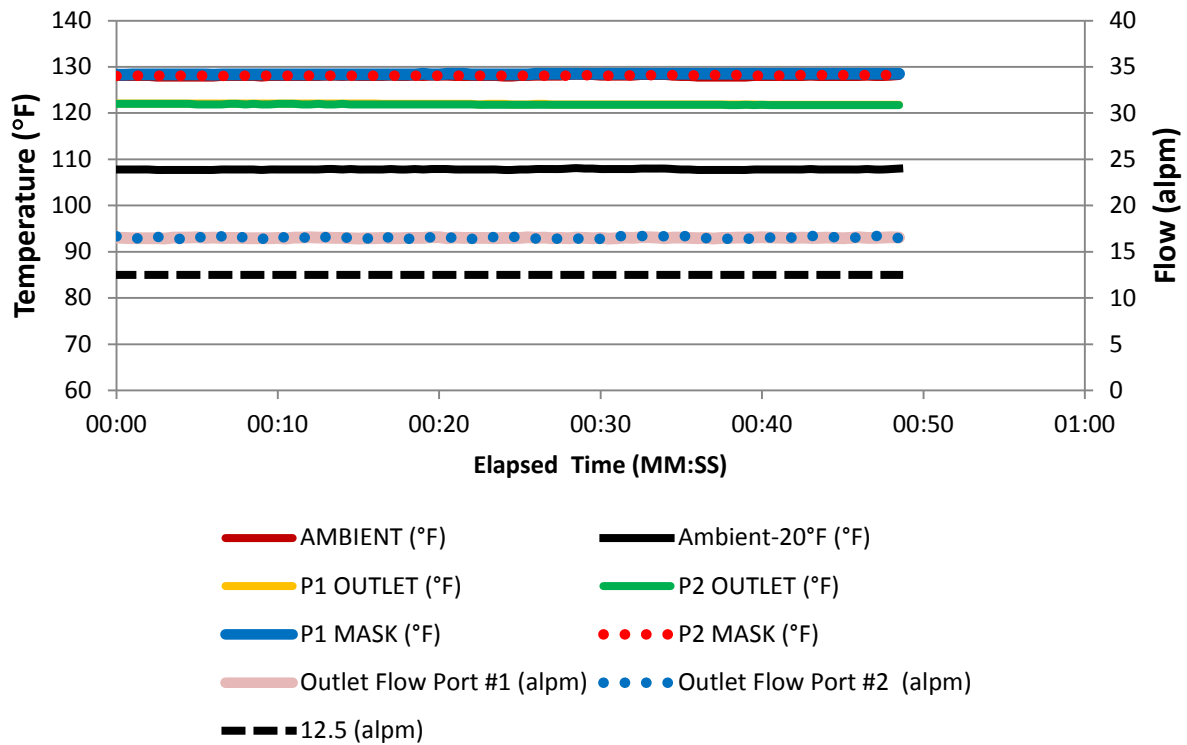


Figure A-31. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; +130°F; Vertical; 15 LPM Setting

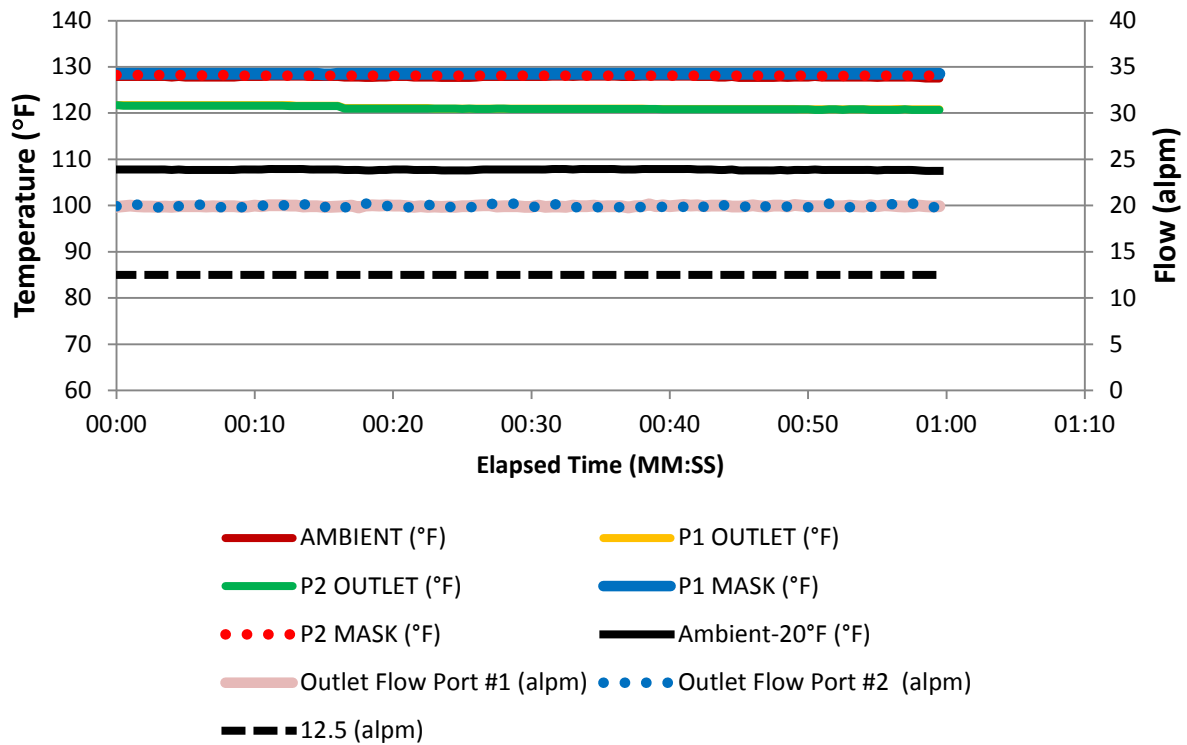


Figure A-32. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; +130F; Vertical; 15 LPM Setting

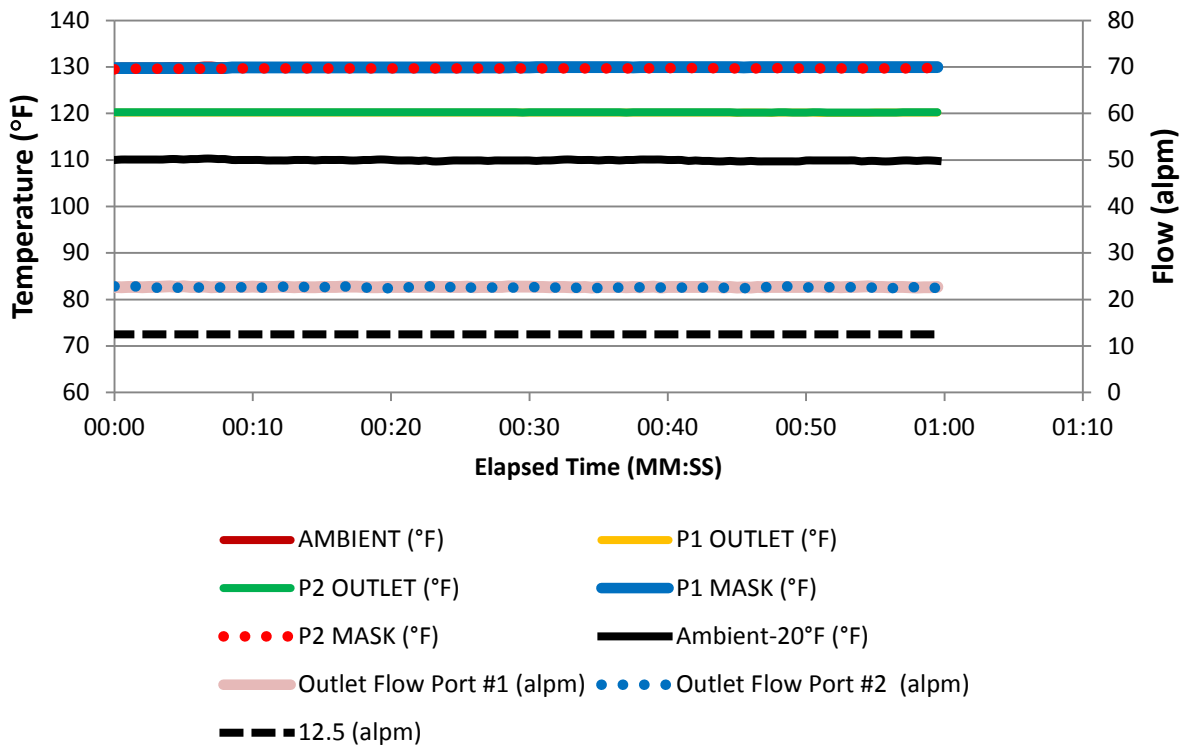


Figure A-33. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; -40°F; Horizontal; 8 LPM Setting

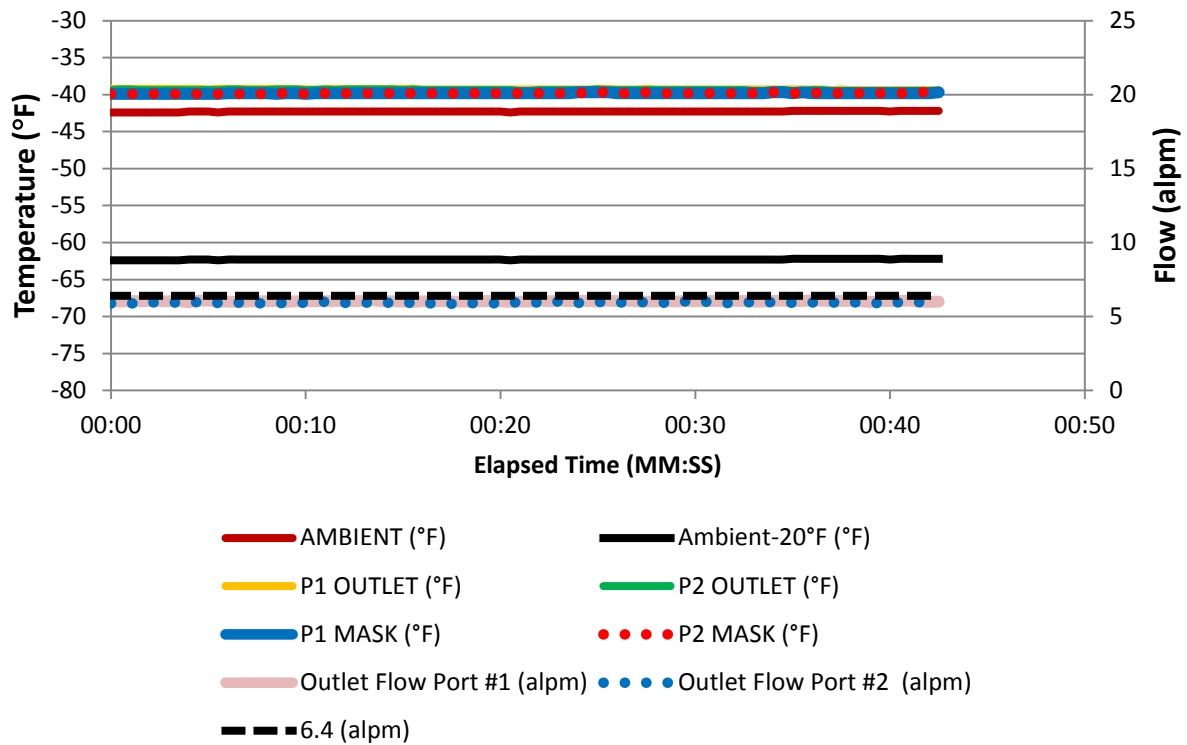


Figure A-34. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; -40°F; Horizontal; 8 LPM Setting

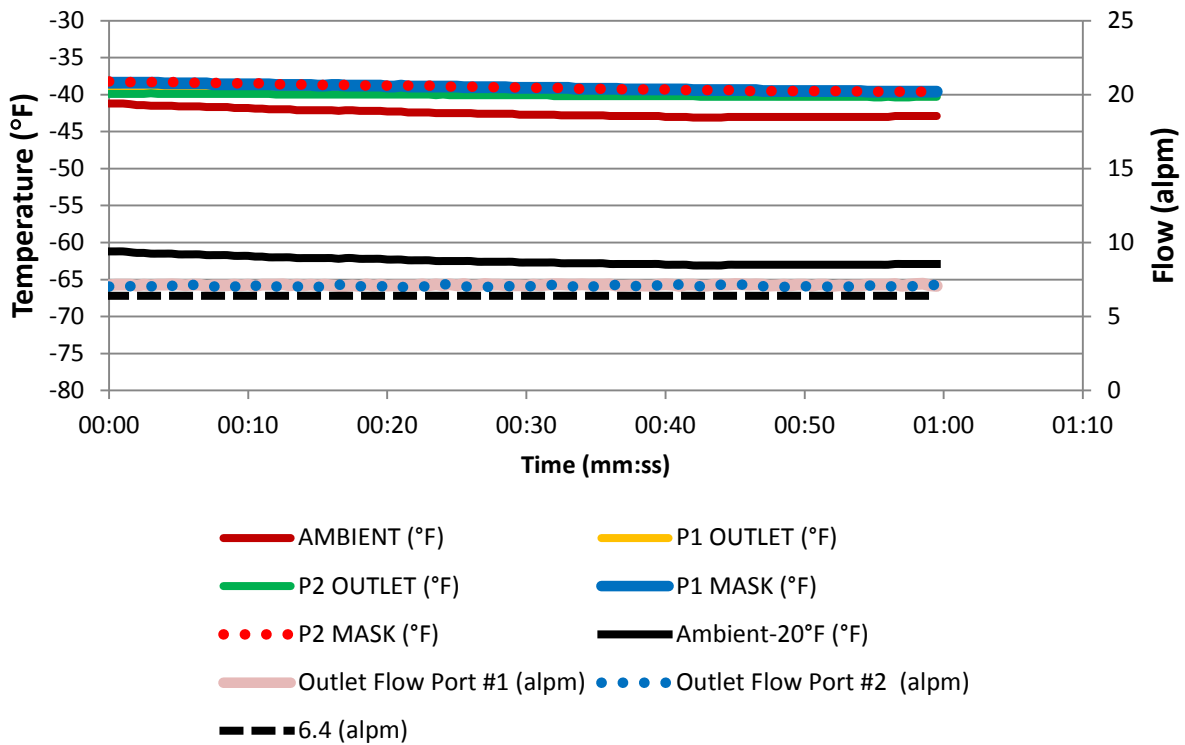


Figure A-35. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; -40°F; Horizontal; 8 LPM Setting

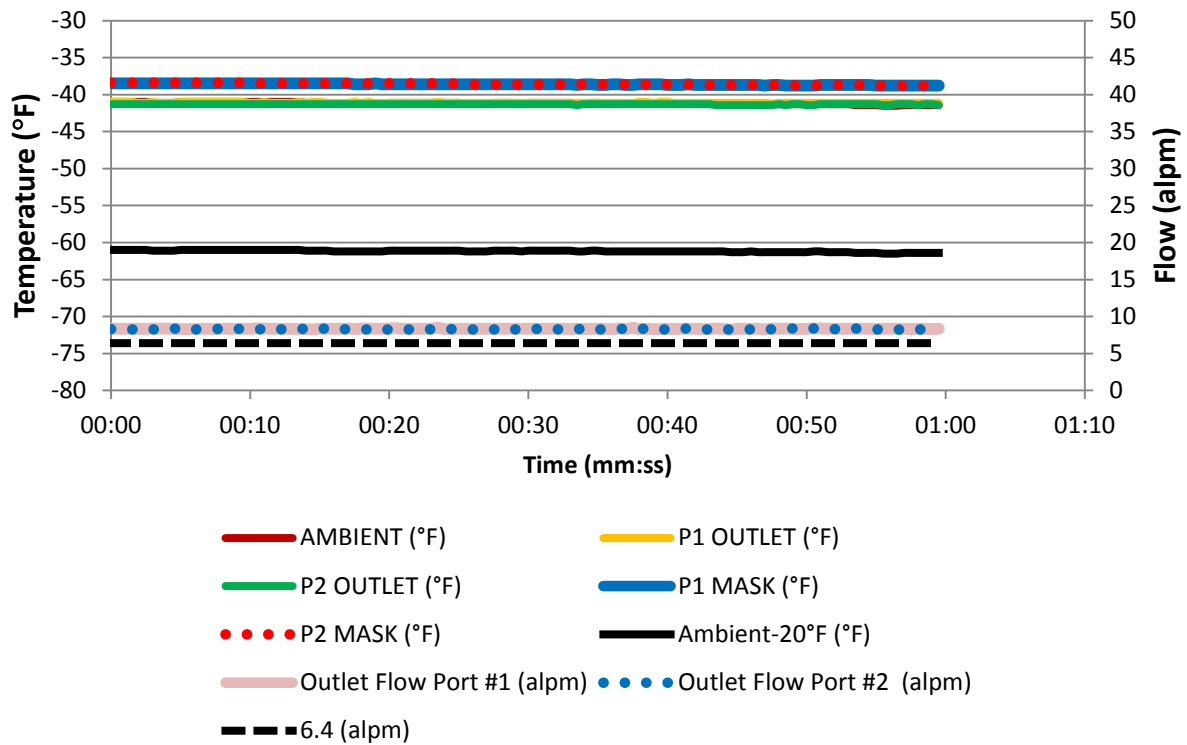


Figure A-36. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; -40°F; Horizontal; 8 LPM Setting

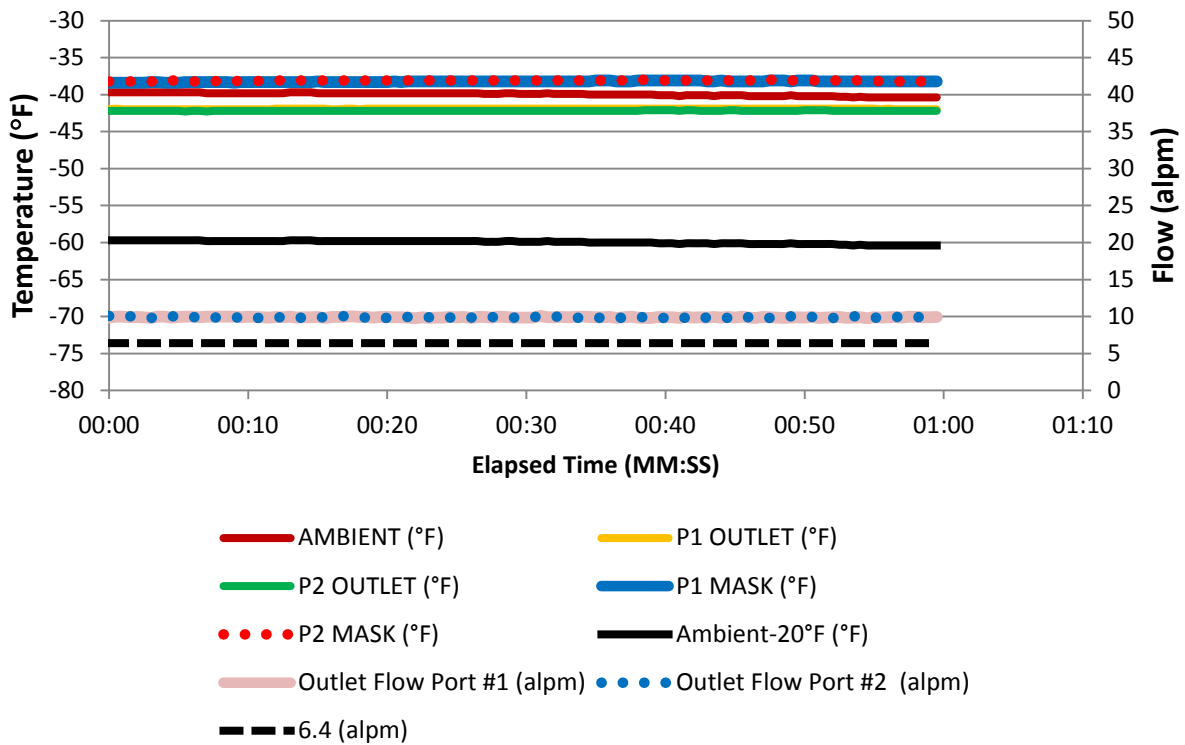


Figure A-37. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; -40°F; Horizontal; 15 LPM
Setting

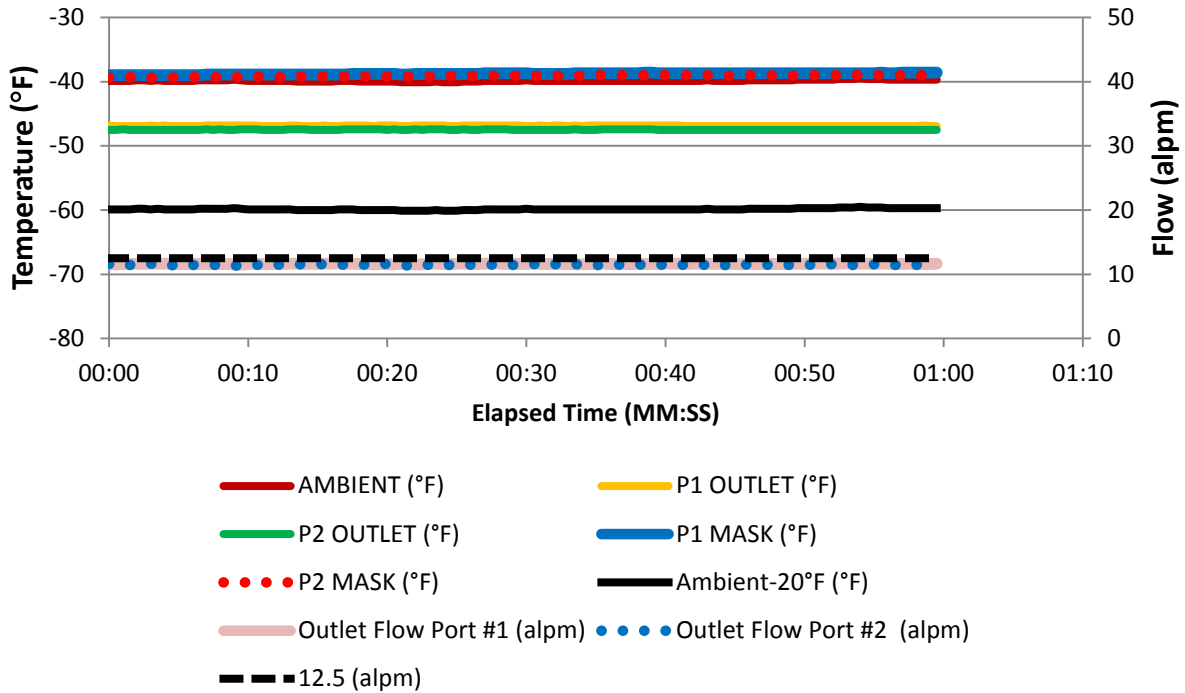


Figure A-38. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; -40°F; Horizontal; 15 LPM Setting

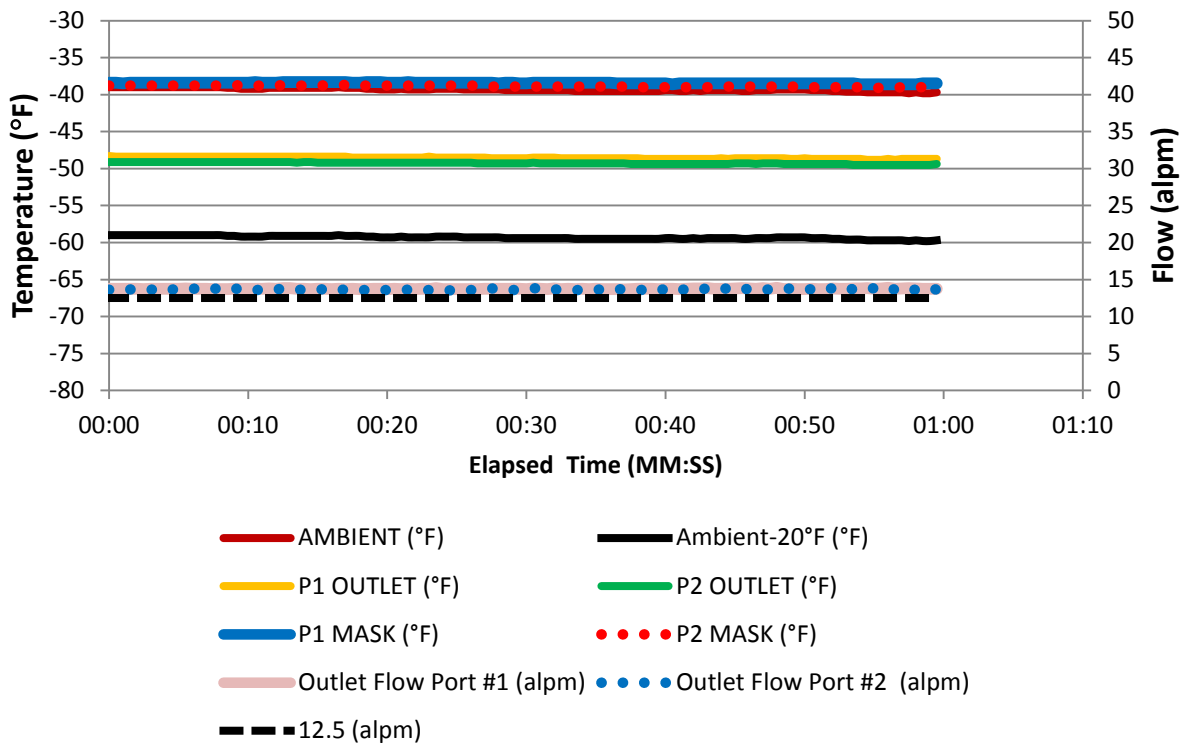


Figure A-39. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; -40°F; Horizontal; 15 LPM Setting

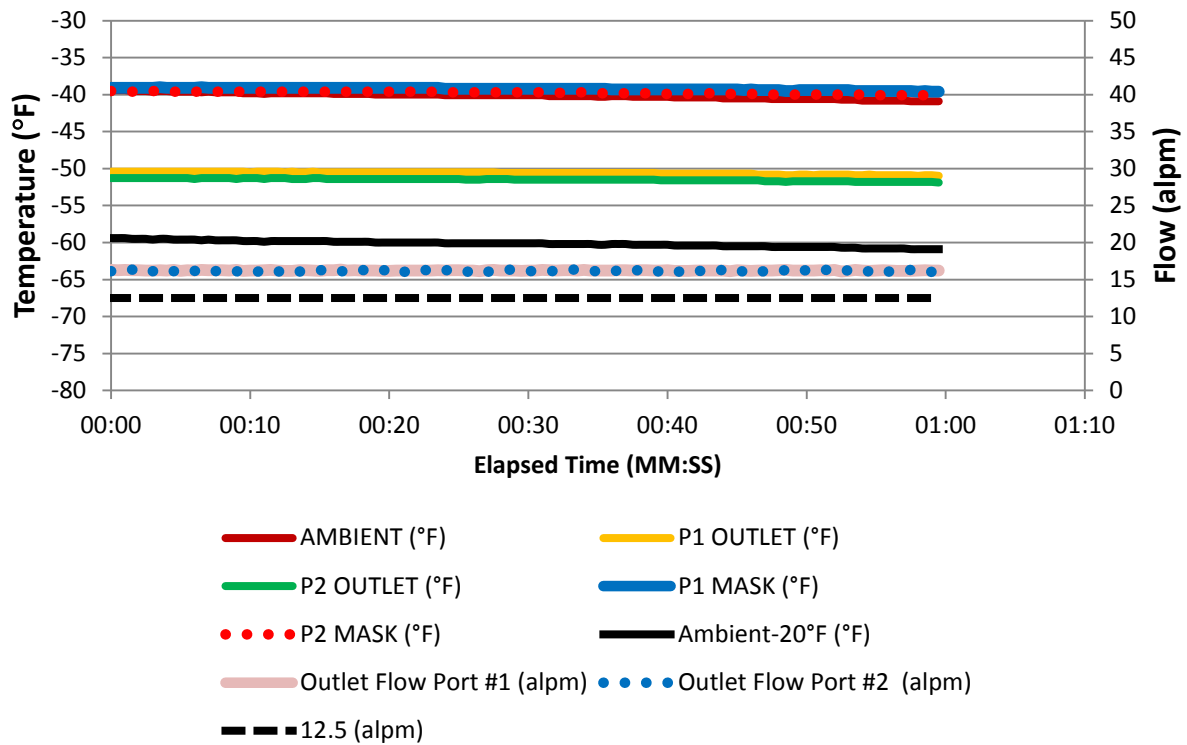


Figure A-40. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; -40°F; Horizontal; 15 LPM Setting

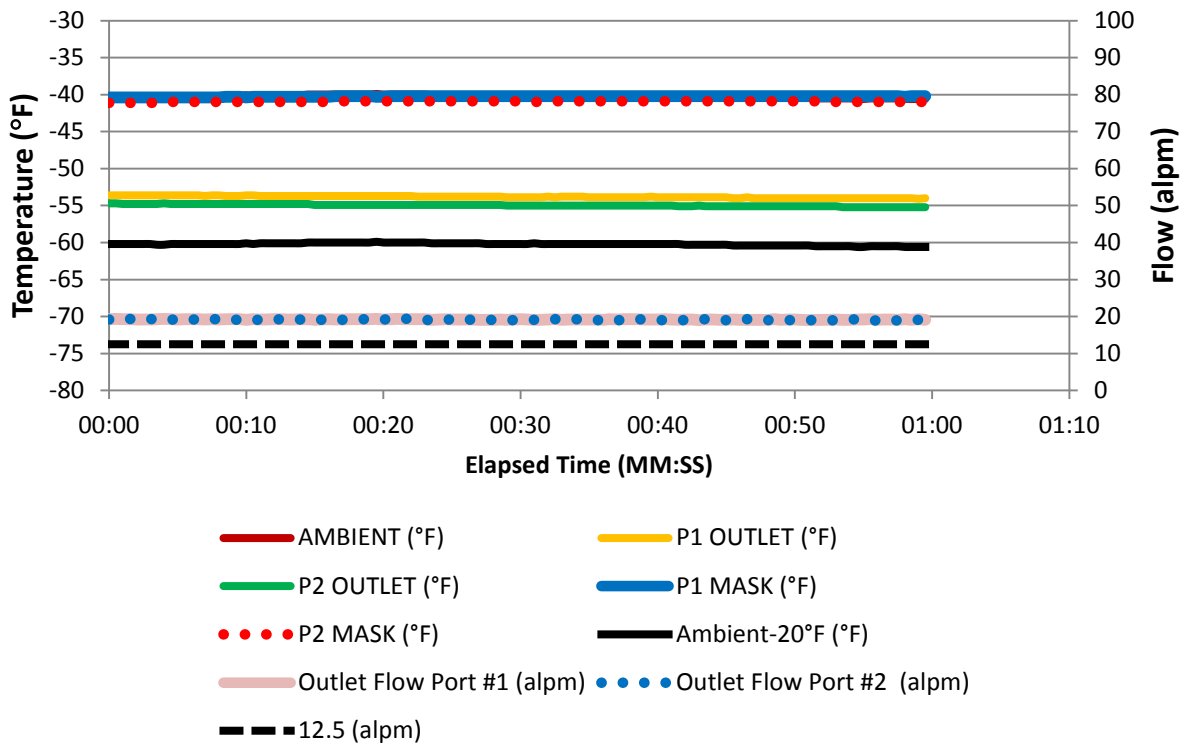


Figure A-41. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; -40°F; Vertical; 8 LPM Setting

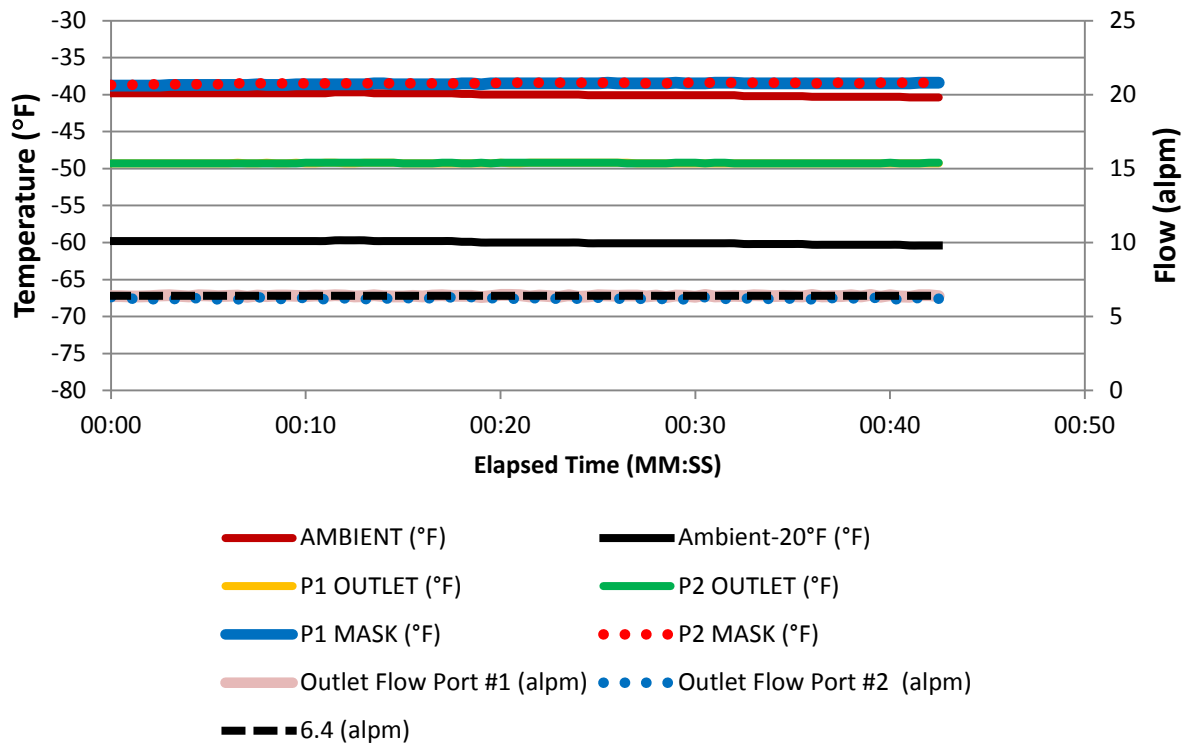


Figure A-42. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; -40°F; Vertical; 8 LPM Setting

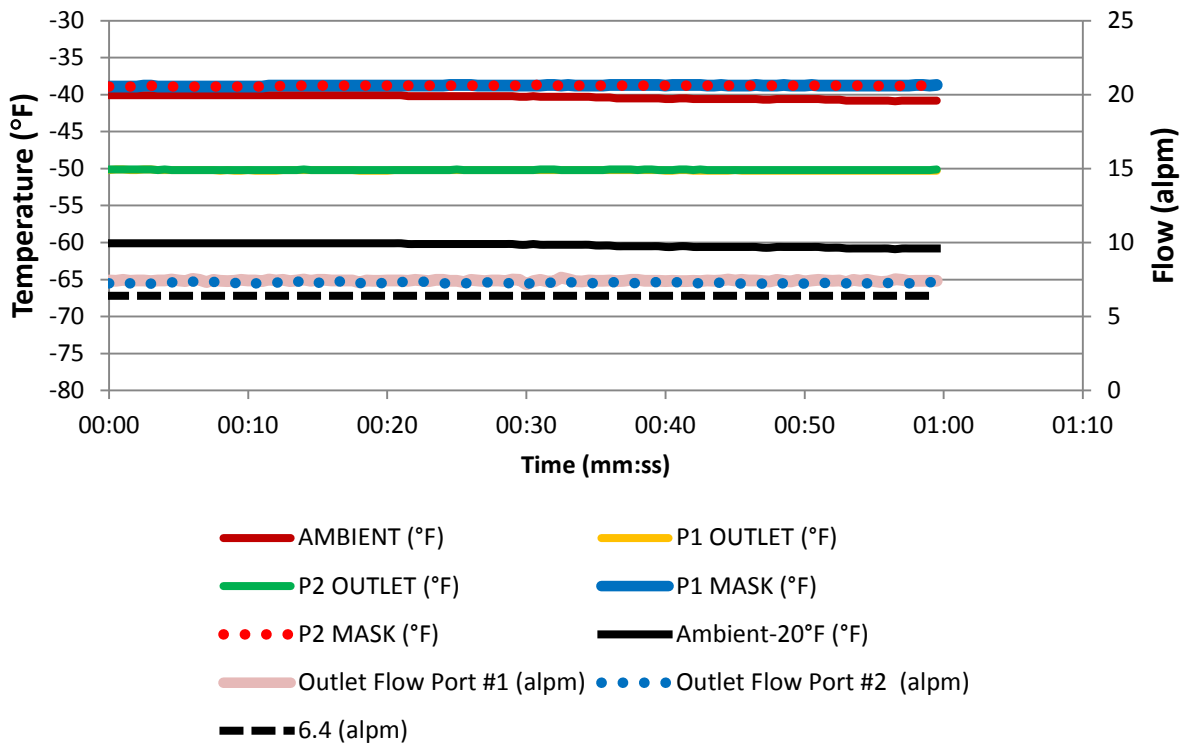


Figure A-43. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; -40°F; Vertical; 8 LPM Setting

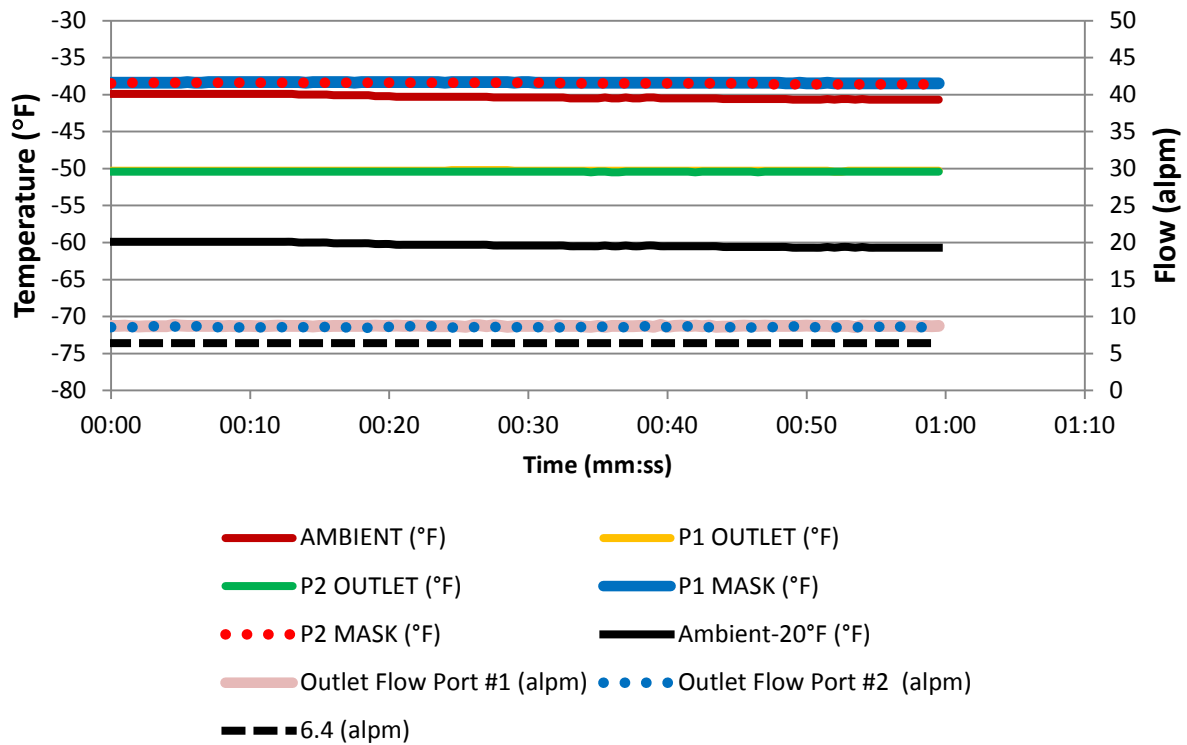


Figure A-44. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; -40°F; Vertical; 8 LPM Setting

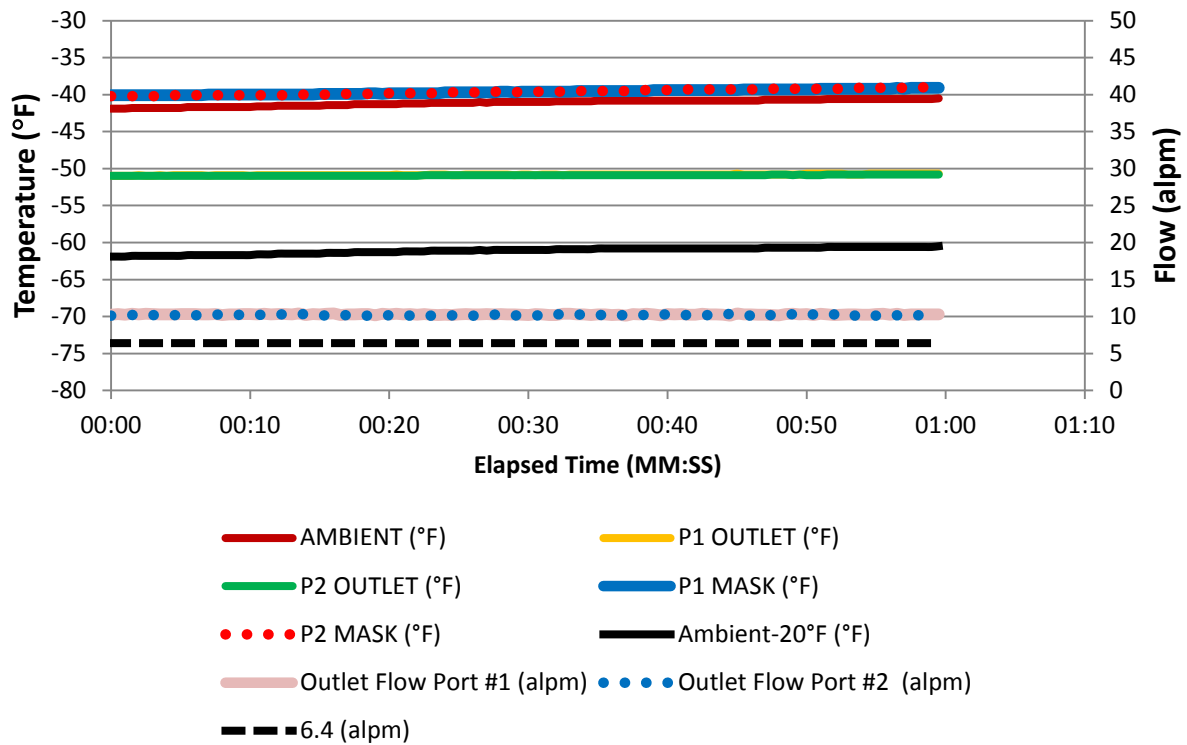


Figure A-45. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; Ground Level; -40°F; Vertical; 15 LPM Setting

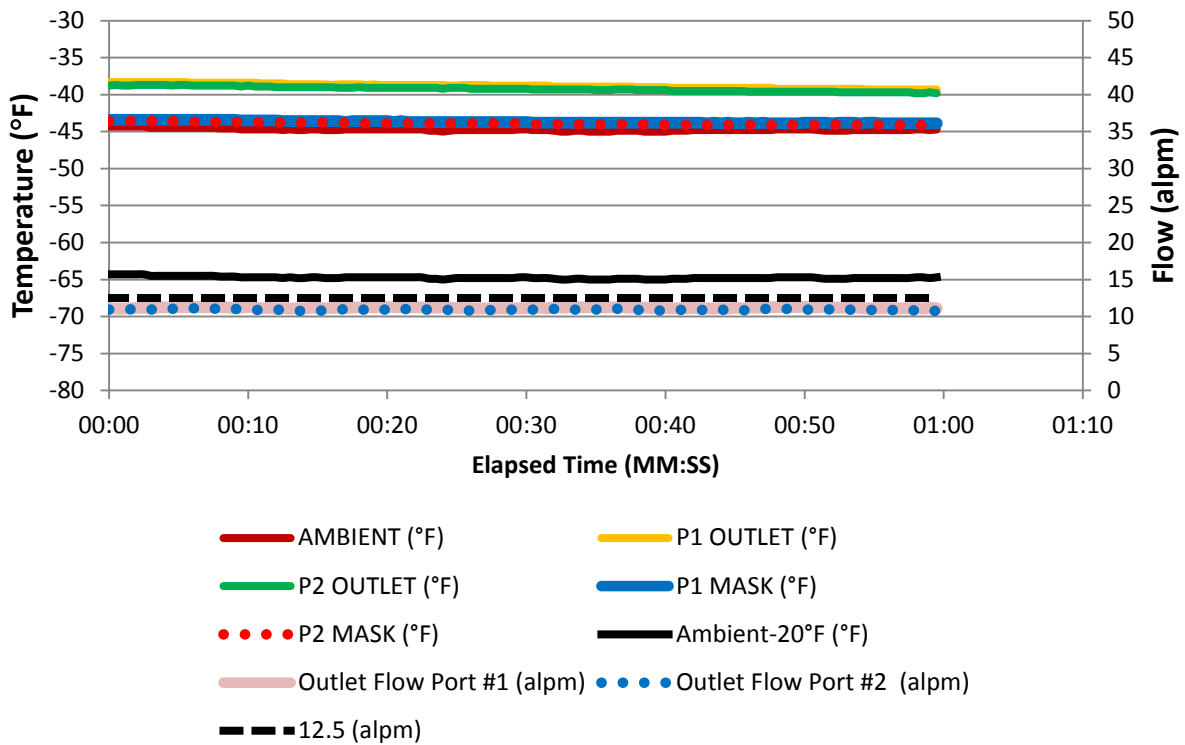


Figure A-46. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 5K FT; -40°F; Vertical; 15 LPM Setting

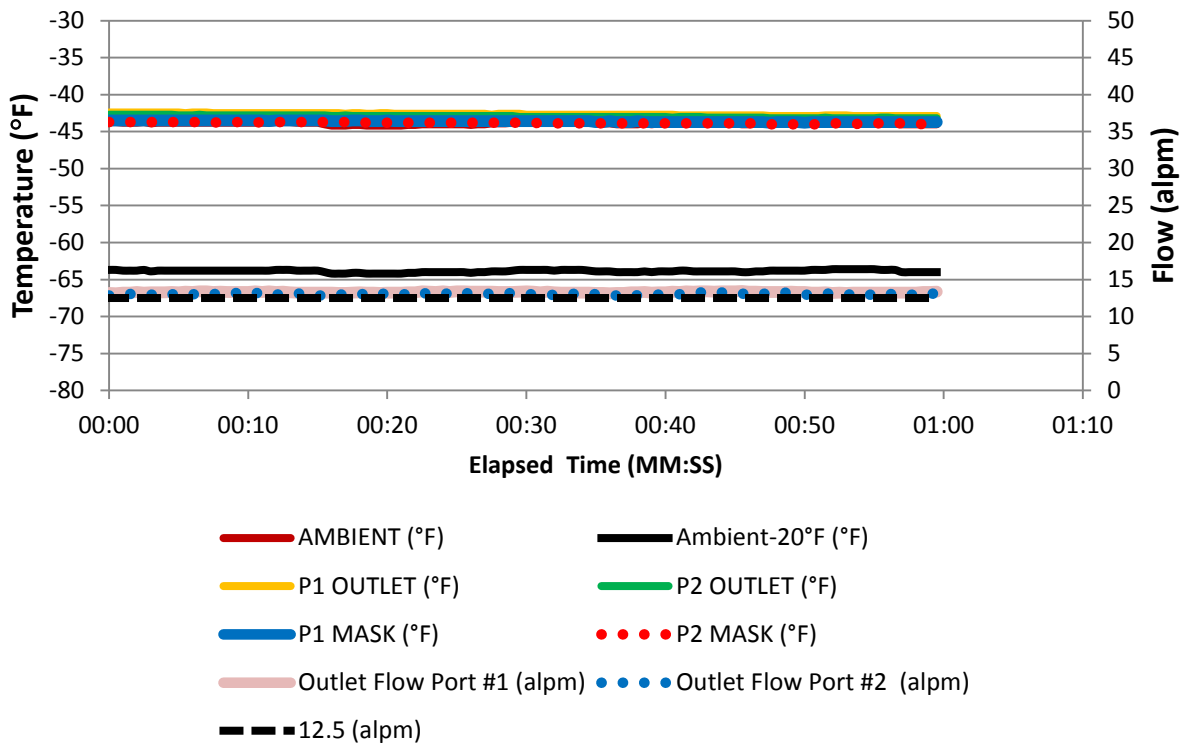


Figure A-47. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 10K FT; -40°F; Vertical; 15 LPM Setting

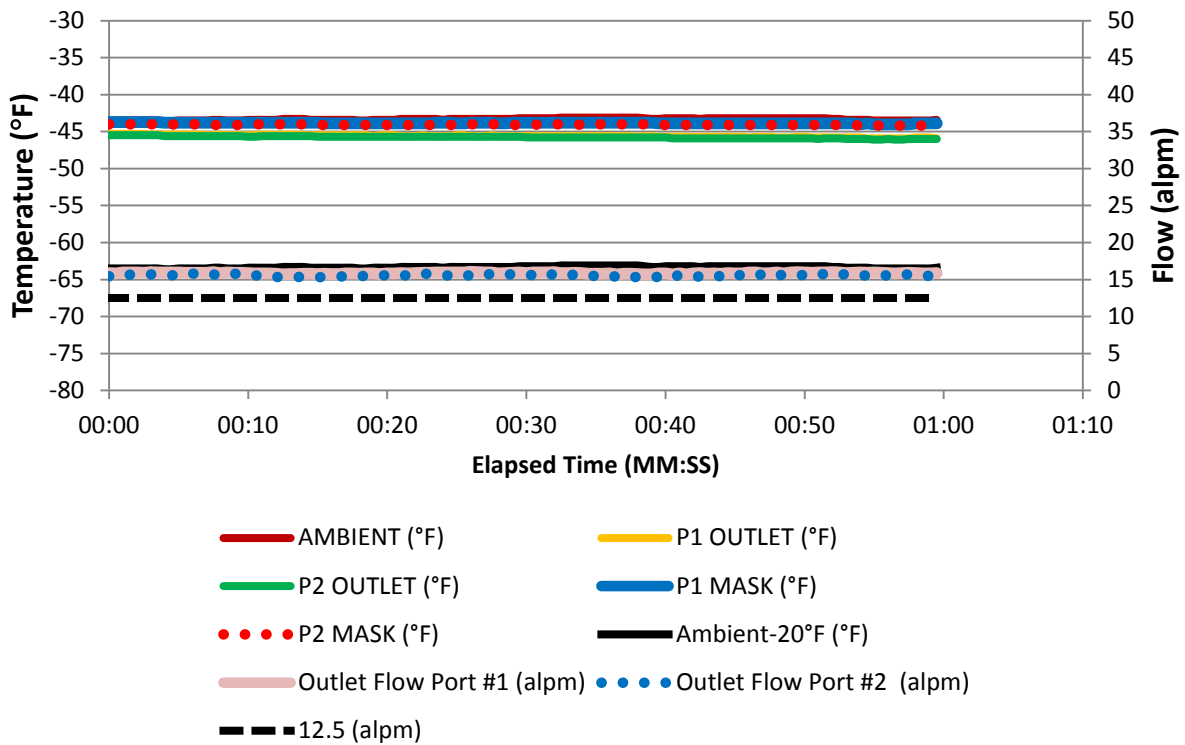


Figure A-48. GUARDIAN ANGEL MMOS TEST (S/N 1010)
Unmanned; 15K FT; -40°F; Vertical; 15 LPM Setting

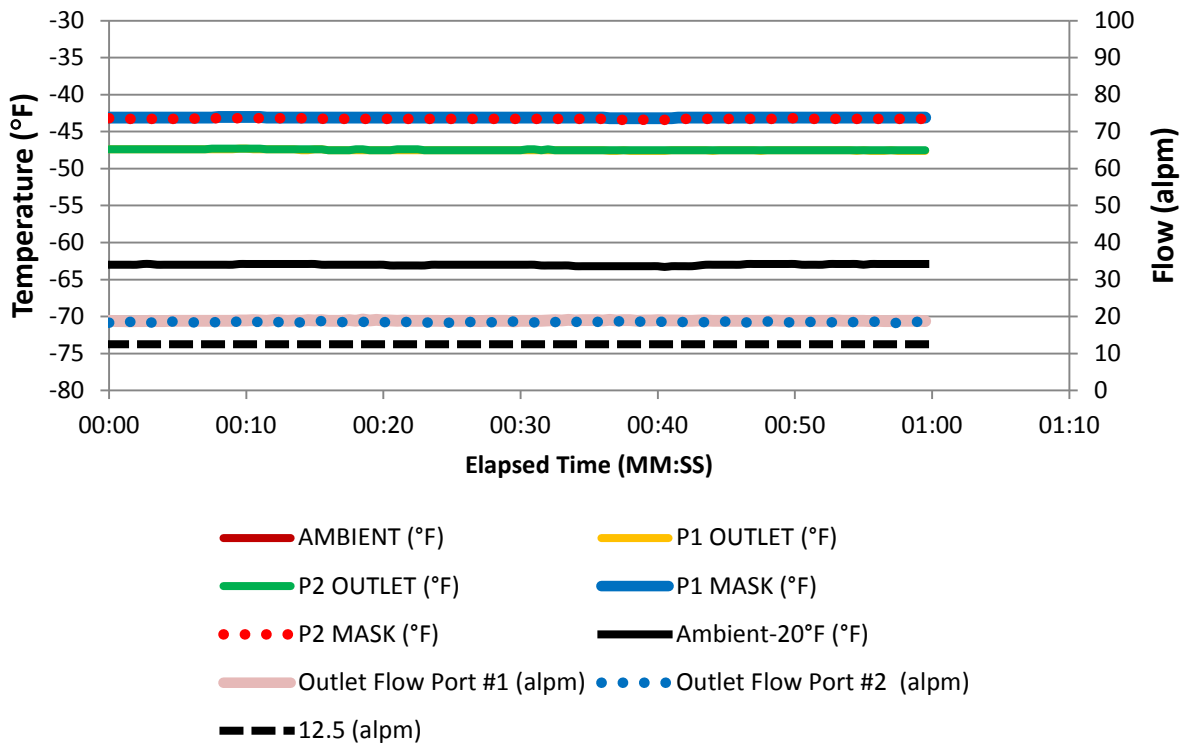


Figure A-49. GUARDIAN ANGEL MMOS TEST (S/N P1010)

**Unmanned; Decompression Horizontal; 8 LPM Setting;
O2 concentration: 94.3%**

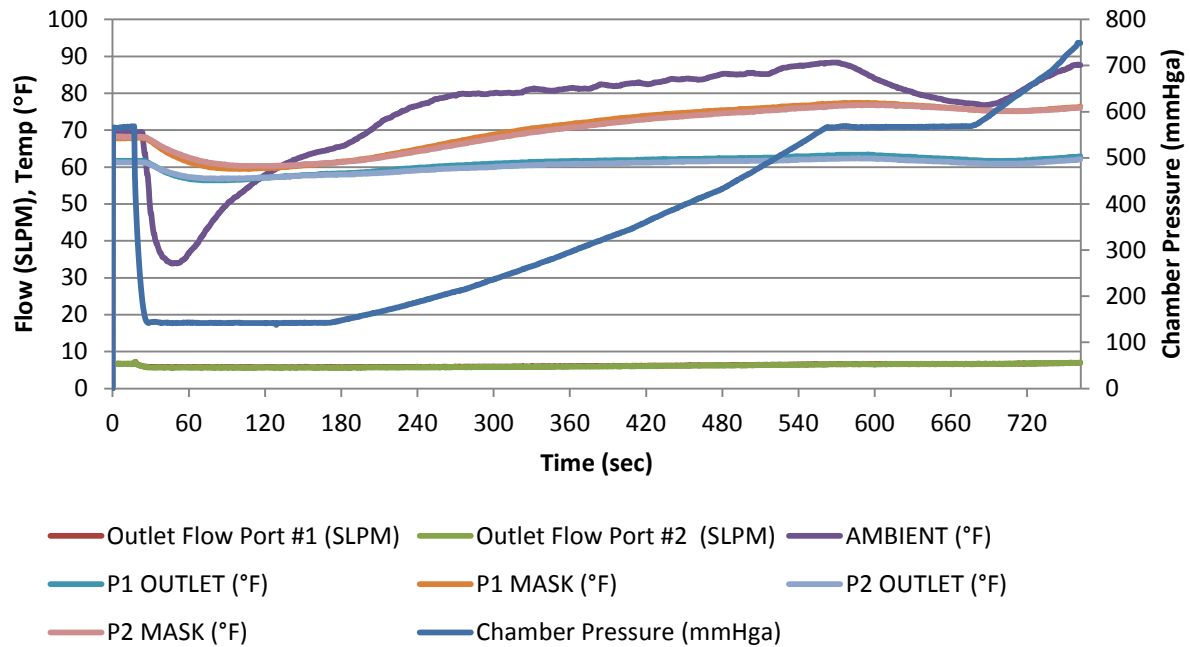


Figure A-50. GUARDIAN ANGEL MMOS TEST (S/N P1010)
Unmanned; Decompression Horizontal; 15 LPM Setting;
O2 concentration: 94.3%

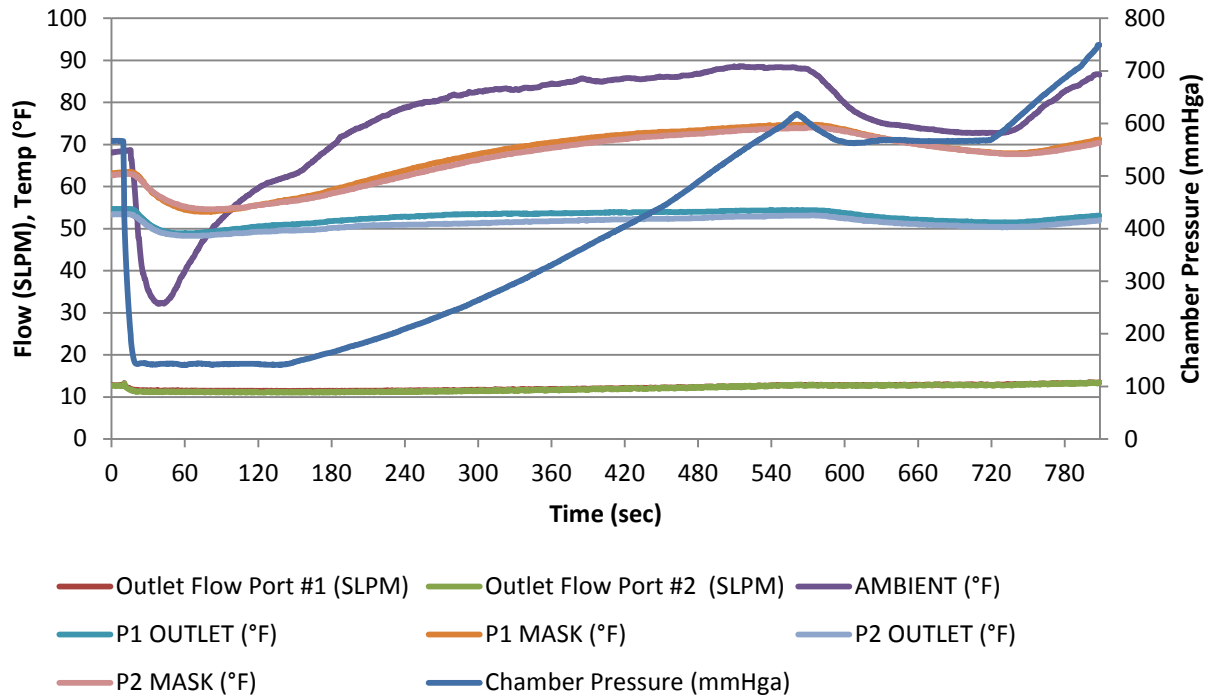


Figure A-51. GUARDIAN ANGEL MMOS TEST (S/N P1010)

**Unmanned; Decompression Vertical; 8 LPM Setting;
O2 concentration: 94.3%**

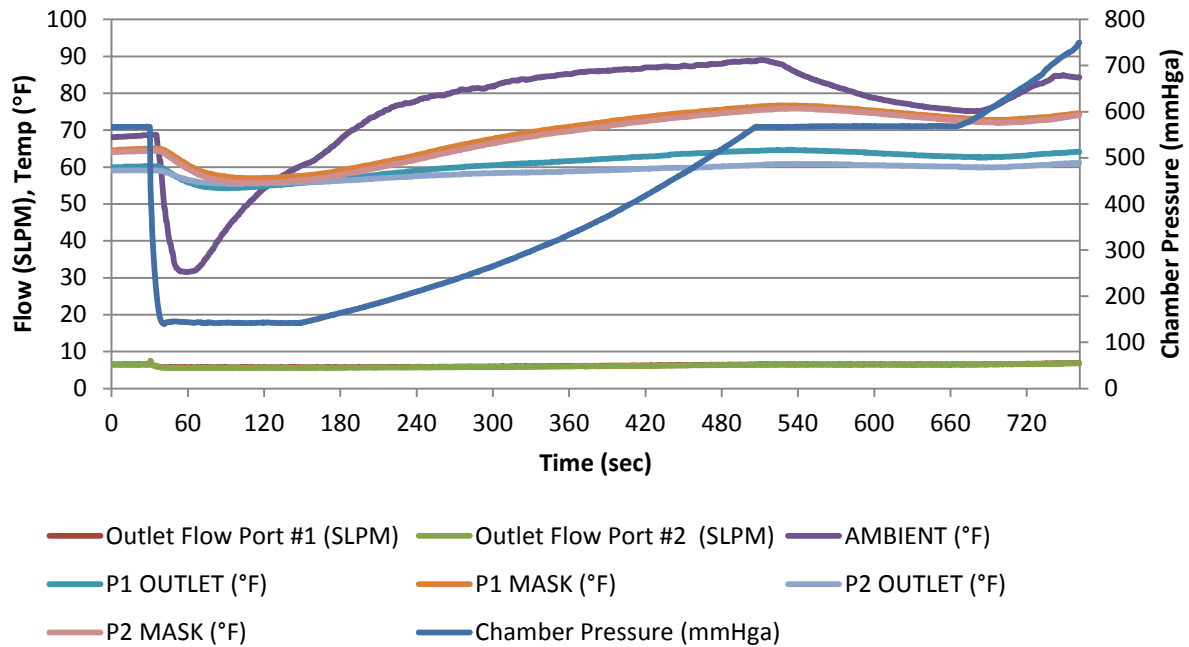
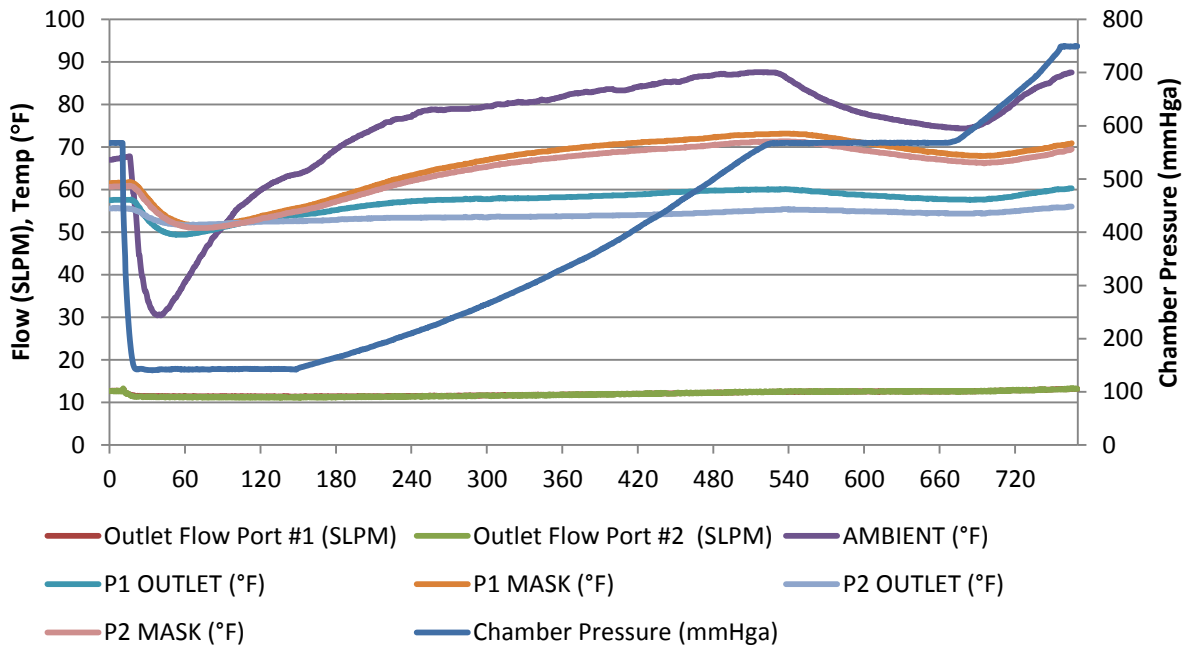


Figure A-52. GUARDIAN ANGEL MMOS TEST (S/N P1010)

Unmanned; Decompression Vertical; 15 LPM Setting;
O2 concentration: 94.3%



APPENDIX B: MMOS Manned Data

Figure B-1. GUARDIAN ANGEL MMOS TEST (S/N P1010)
Run #1; Manned; 15 KFT; Two PJs; Medical Masks; MMOS Horizontal;
Flow Minimum Investigation

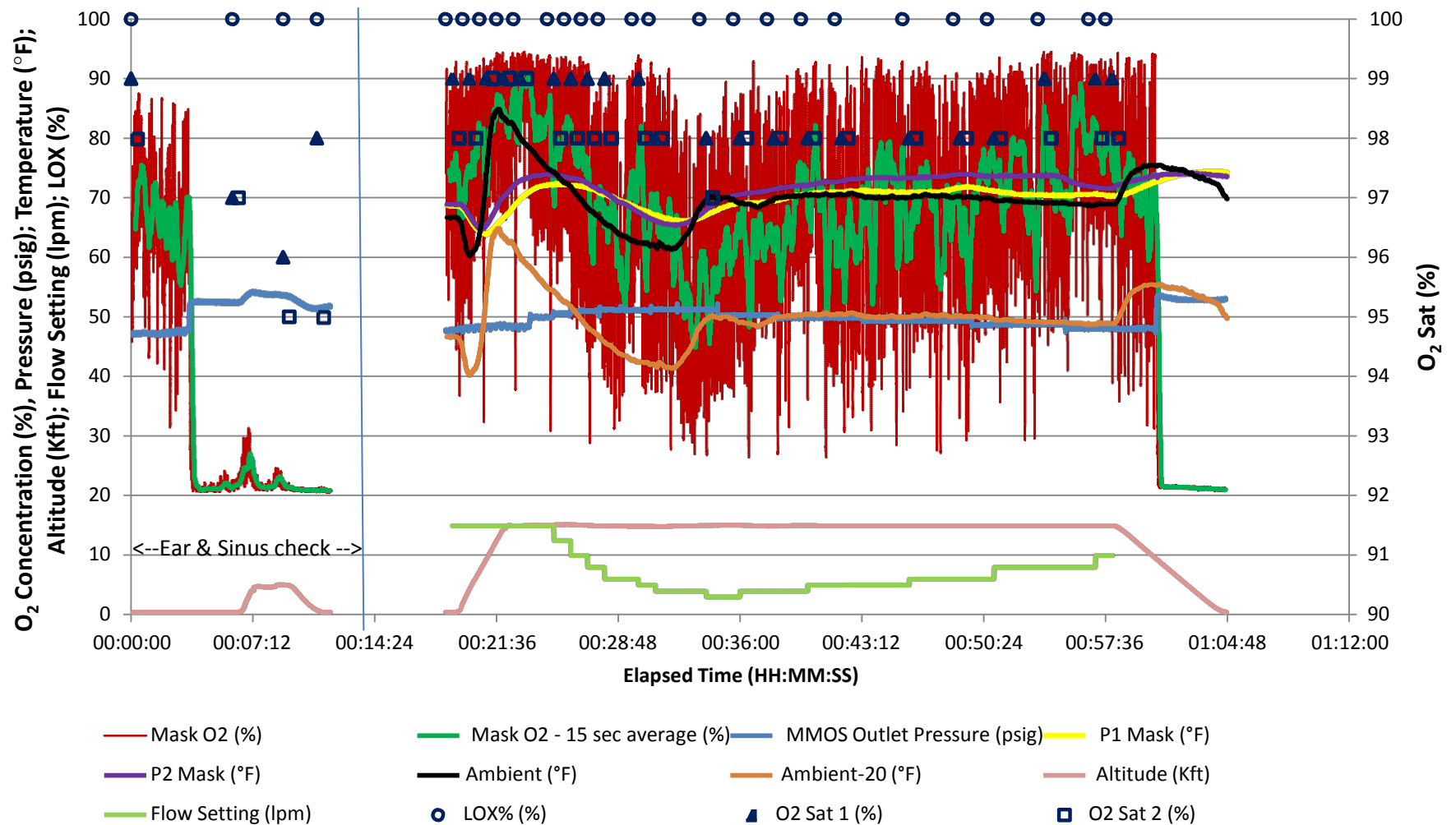


Figure B-2. GUARDIAN ANGEL MMOS TEST (S/N P1010)
Run #2; Manned; 15 KFT; Two PJs; Medical Masks; MMOS Vertical;
Flow Minimum Investigation

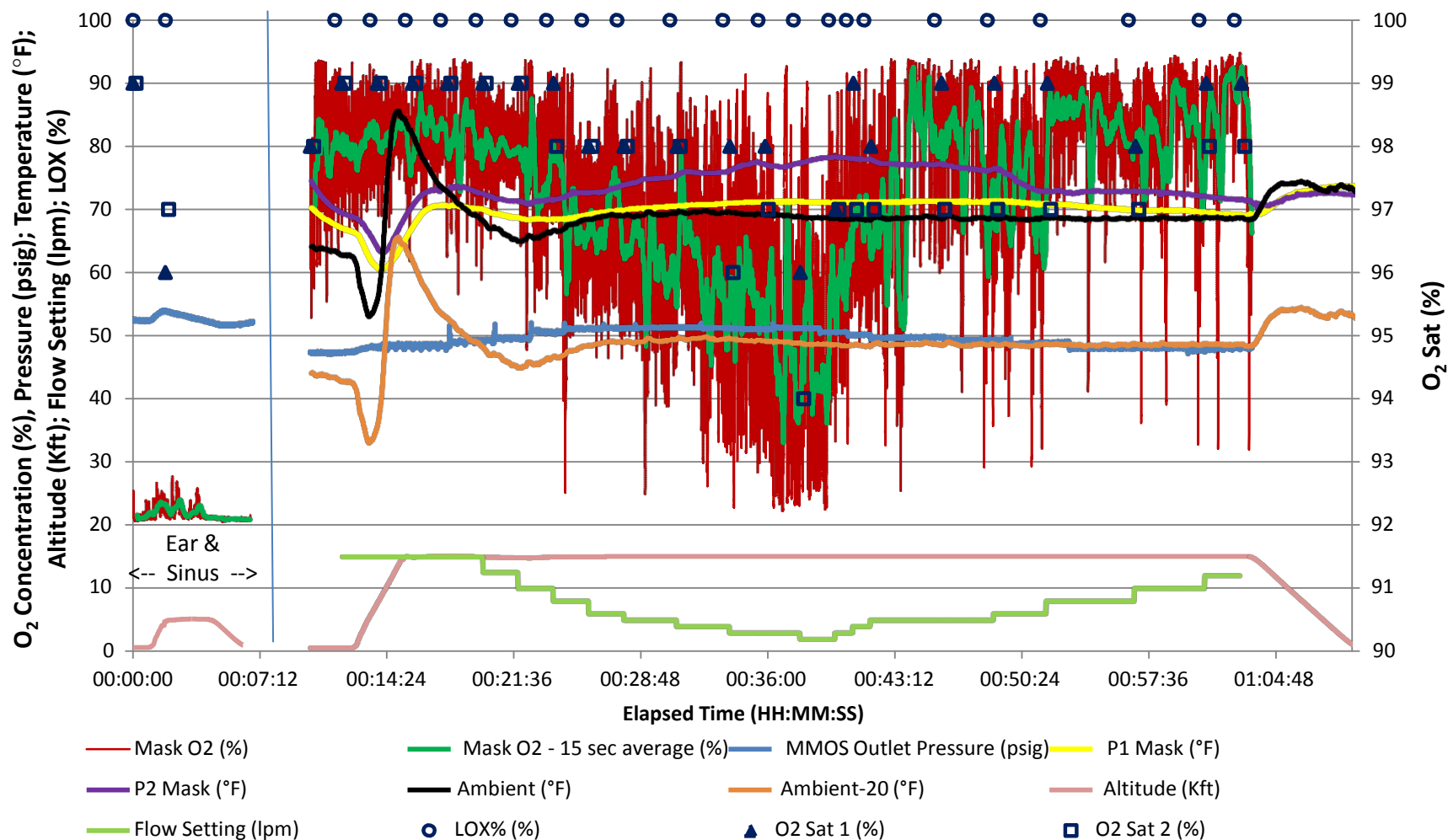
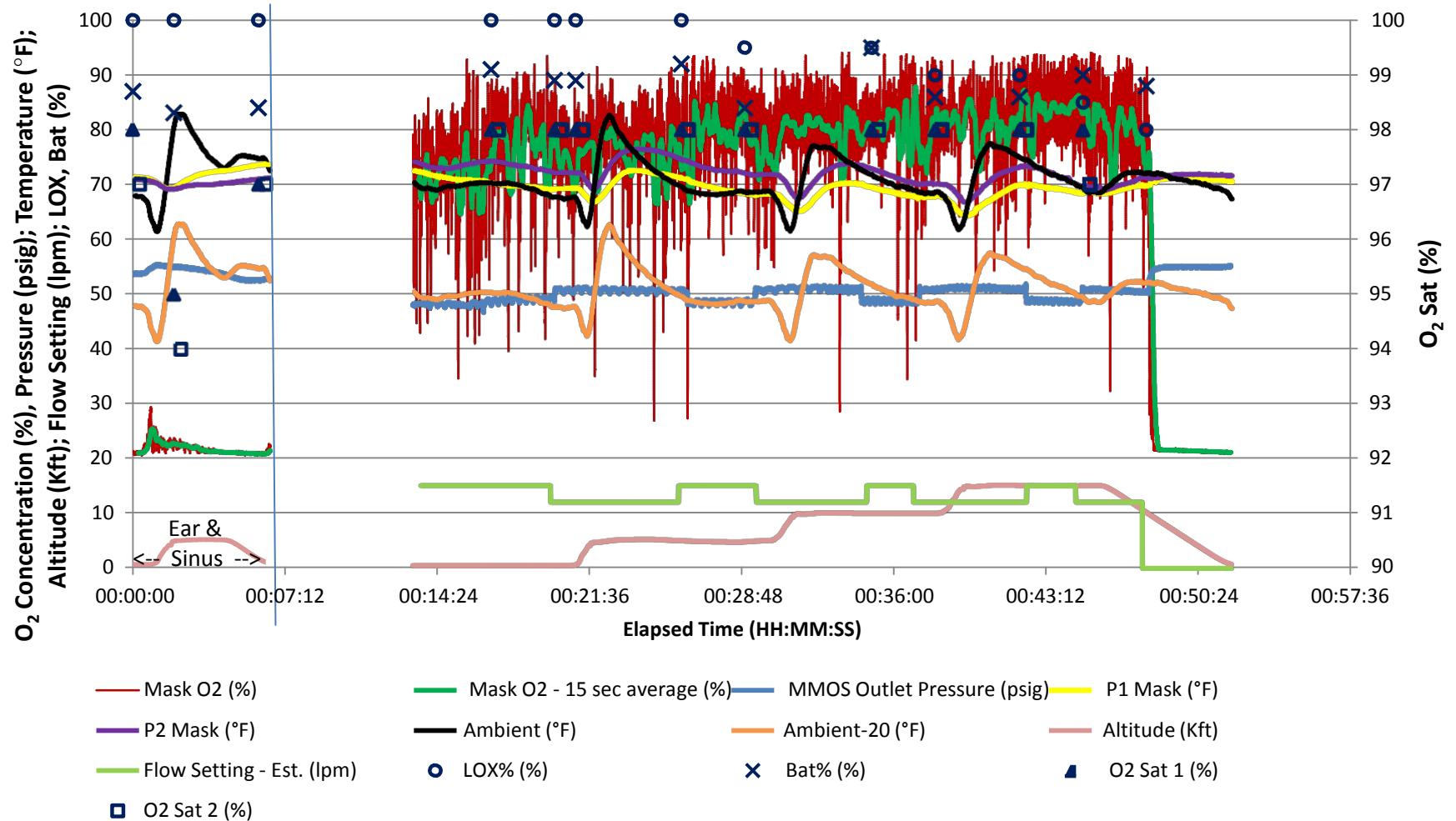


Figure B-3. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #3; Manned; 5KFT-10KFT-15KFT; Two PJs; Medical Masks;
MMOS Horizontal; Room Temperature



**Figure B-4. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #4; Manned; Ground Level; Two PJs; Medical Masks;
MMOS Horizontal; +130°F**

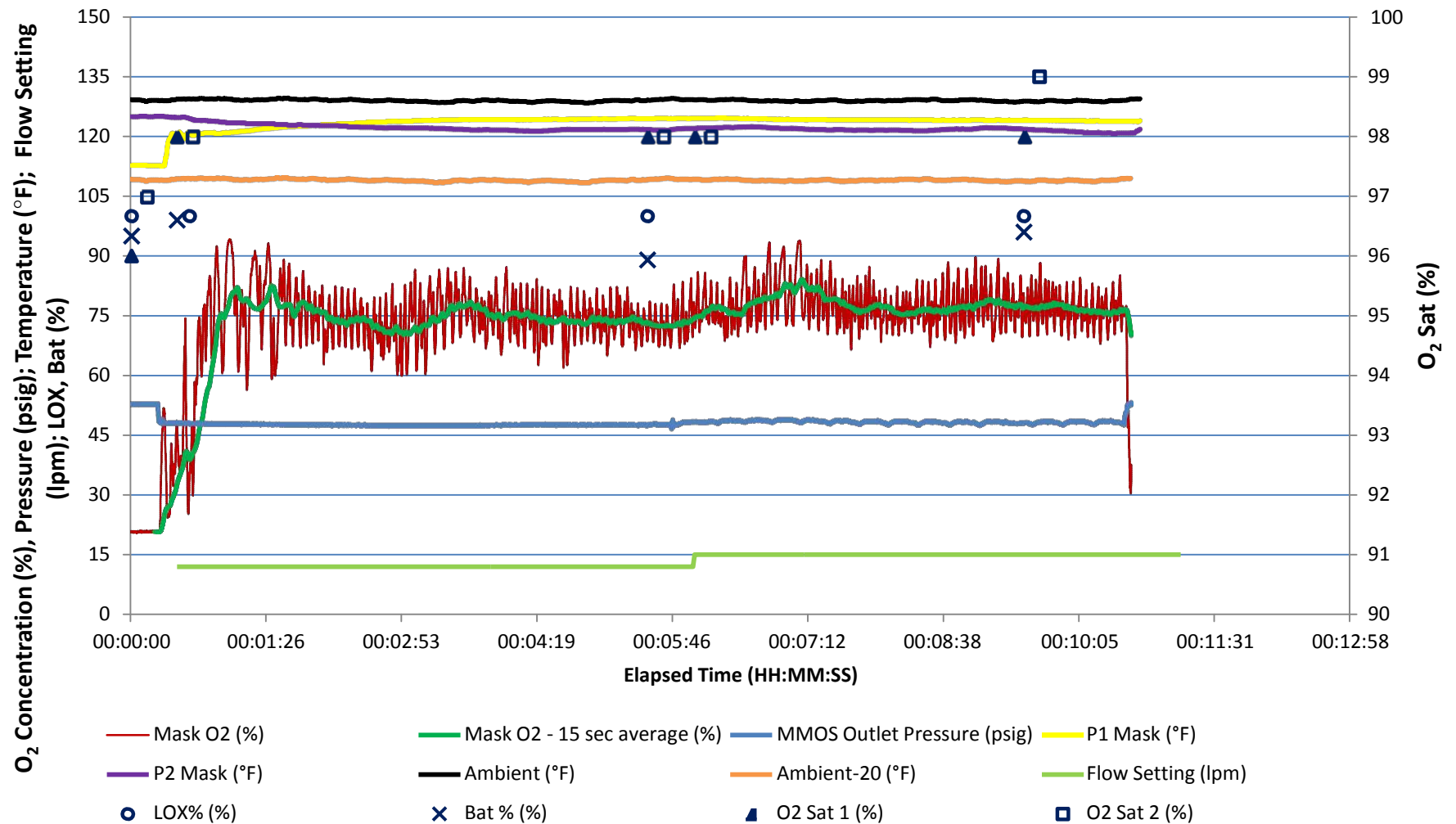
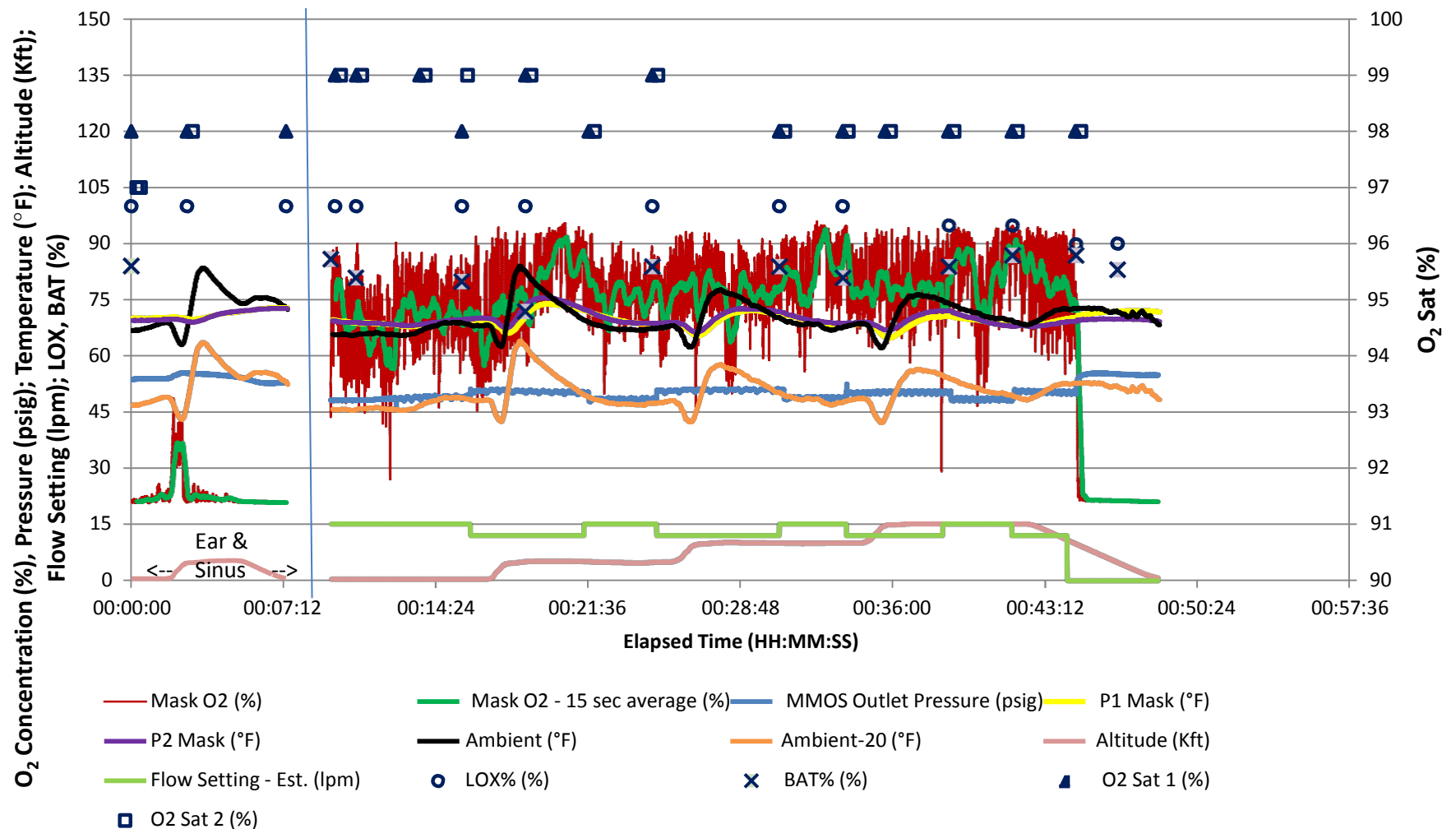


Figure B-5. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #5; Manned; 5KFT-10KFT-15 KFT; Two PJs; Medical Masks;
MMOS Vertical; Room Temperature



**Figure B-6. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #6; Manned; Ground Level; Two PJs; Medical Masks;
MMOS Vertical; +130°F**

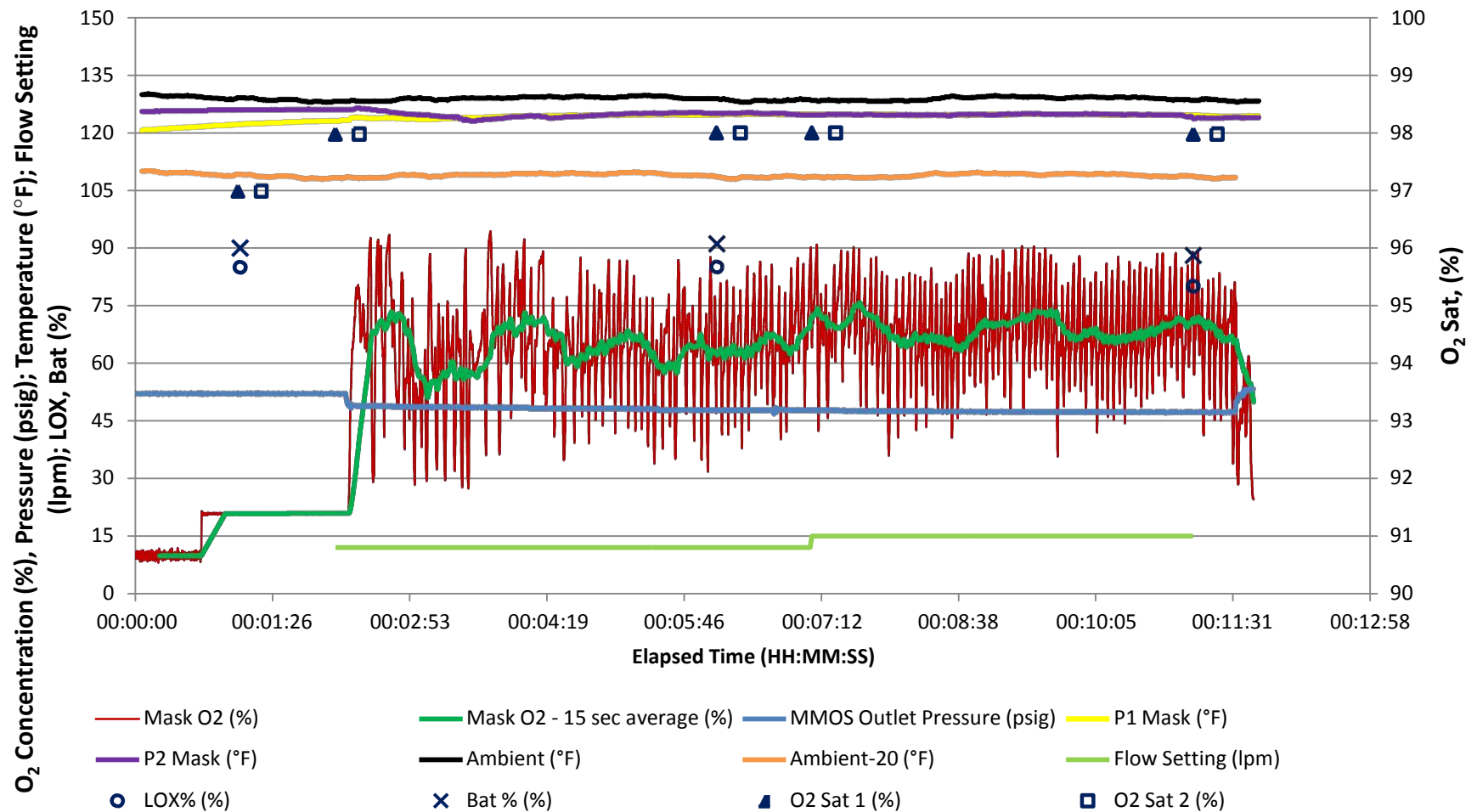


Figure B-7. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #7; Ventilator Only; GL & 15KFT; Two PJs Using Chamber Masks;
MMOS Horizontal; Room Temperature

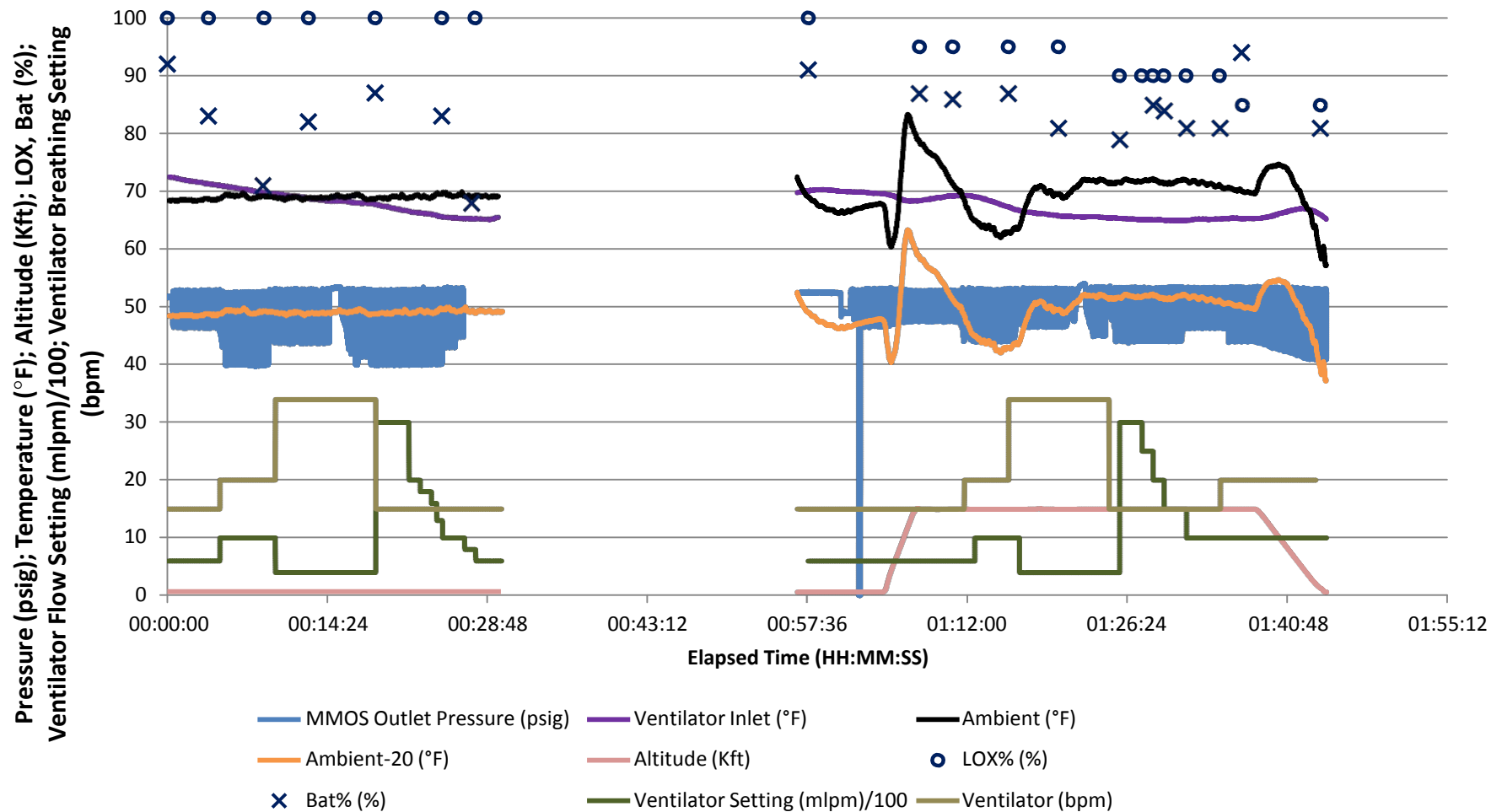


Figure B-8. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #8; Manned; Ground Level; Two PJs; Medical Masks;
MMOS Horizontal; -40°F

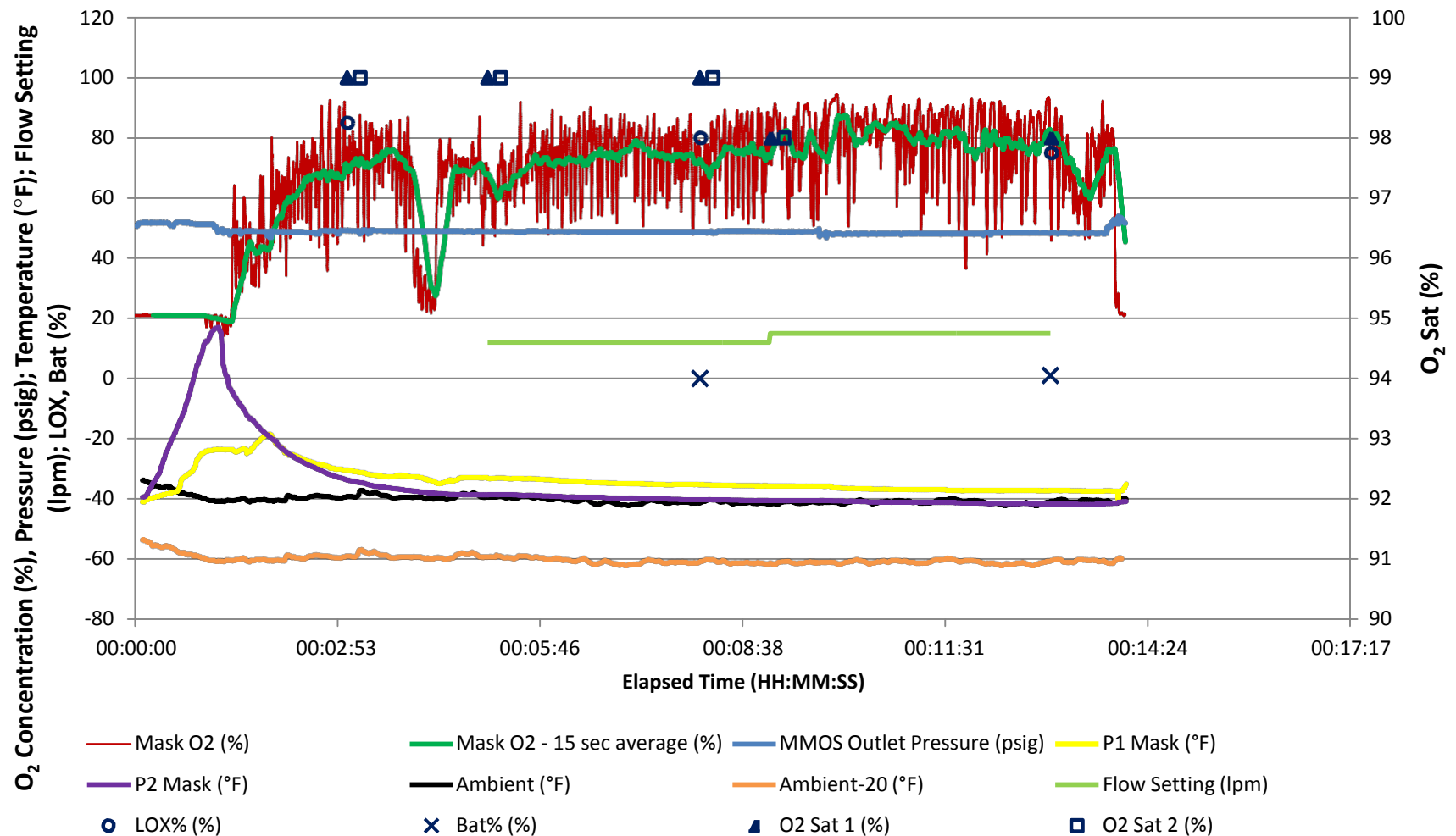


Figure B-9. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #9; Ventilator Only; GL & 15KFT; Two PJs Using Chamber Masks;
MMOS Vertical; Room Temperature

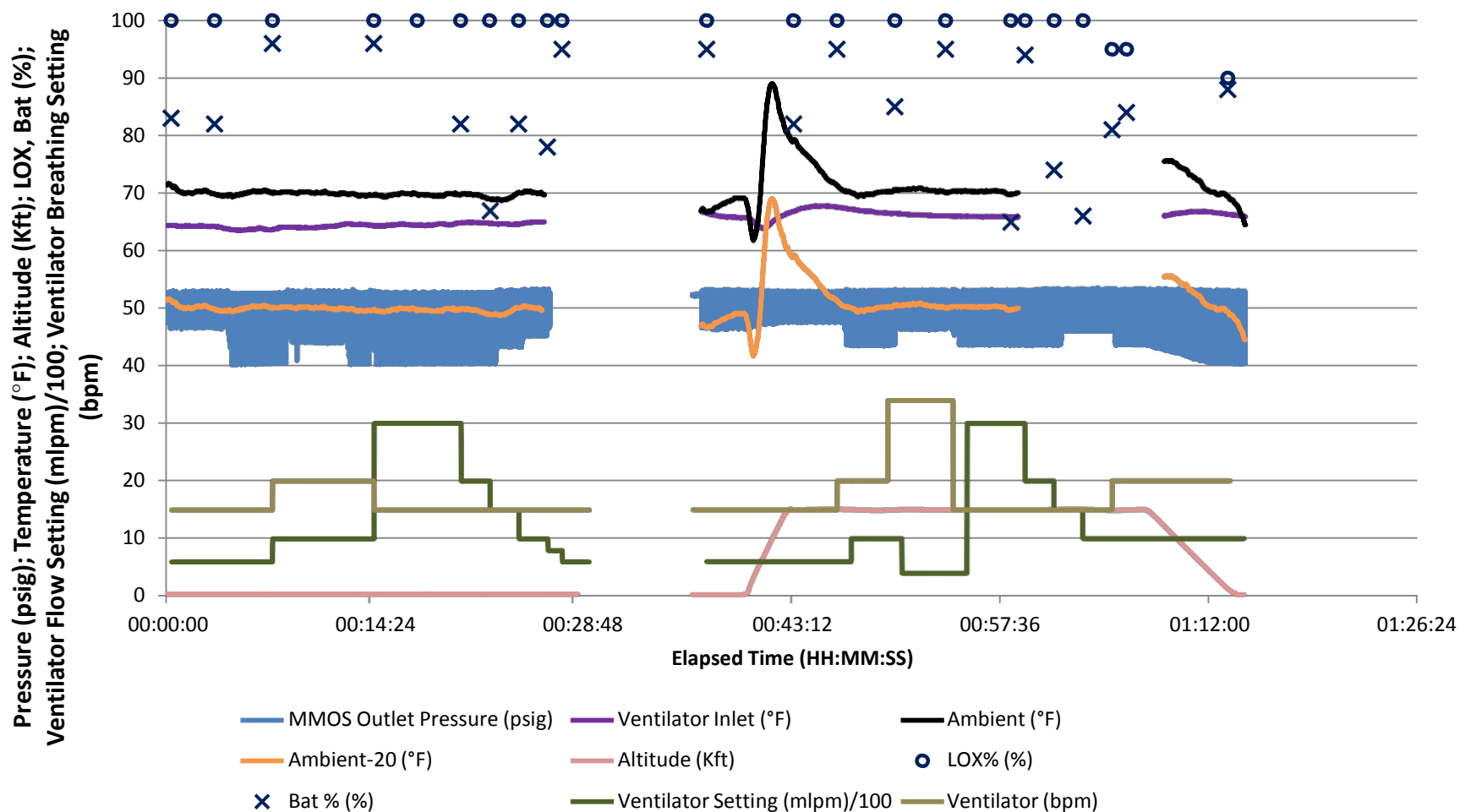
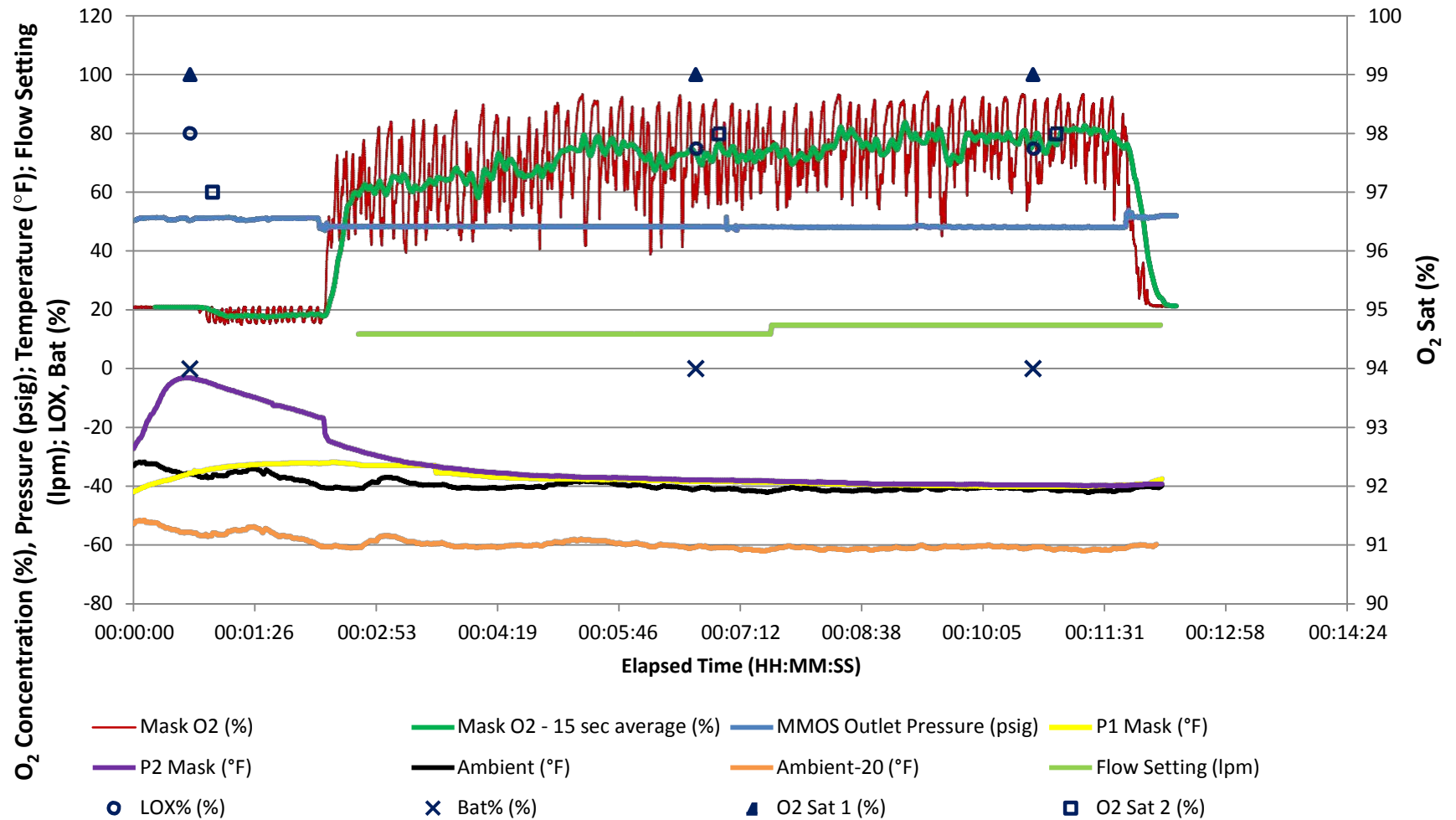


Figure B-10. GUARDIAN ANGEL MMOS TEST (S/N P1011)
Run #10; Manned; Ground Level; Two PJs; Medical Masks;
MMOS Vertical; -40°F



APPENDIX C: MMOS Questionnaires

S/N P1010

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Number: <u>Mask # 5</u>	Date/Time <u>6 Jan 12 am</u>
Test Number: <u>1</u> <u>Min Flow, Horizontal, 15K ft</u>	
Participant Oxygen Mask (circle): <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Position #1 Oxygen Temperature Sensor Only </div> <div style="text-align: center;"> Position #2 Oxygen % Sensor and Oxygen Temperature Sensor </div> </div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

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MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Number: _____ Mask # 41	Date/Time <u>6 Jan 12 am</u>
Test Number: <u>1</u> Min Flow, Horiz, 15K ft	
Participant Oxygen Mask (circle): <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Position #1 <div style="border: 1px solid black; border-radius: 50%; padding: 2px; display: inline-block;">Oxygen Temperature Sensor Only</div> </div> <div style="text-align: center;"> <div style="border: 1px solid black; border-radius: 50%; padding: 2px; display: inline-block;">Position #2</div> Oxygen % Sensor and Oxygen Temperature Sensor </div> </div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>1</u>	Date/Time <u>6 Jan 1415 HR,</u>
Test Number: <u>2</u> <u>M.n Flow Vertical</u>	
Participant Oxygen Mask (circle): <div>Position #1 Position #2 <u>O2 % & Temp Sensors</u> O2 Temp only</div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>2</u>	Date/Time <u>6 Jan 1415 HRS</u>
Test Number: <u>2</u>	
Participant Oxygen Mask (circle): Position #1 O2 % & Temp Sensors	
<div style="border: 1px solid black; border-radius: 50%; padding: 10px; display: inline-block;">Position #2 O2 Temp only</div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>4</u>	Date/Time <u>10 am 9 Jan 2012</u>
Test Number: <u>3</u>	
Participant Oxygen Mask (circle): Position #1 <u>O2 % & Temp Sensors</u> Position #2 O2 Temp only	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems. <u>N/A</u>	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>2</u>	Date/Time <u>10 am 9 Jan 2012</u>
Test Number: <u>3</u>	
Participant Oxygen Mask (circle): Position #1 <u>Position #2</u> O2 % & Temp Sensors O2 Temp only	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>1</u>	Date/Time <u>9 Jan 1300</u>
Test Number: <u>4</u>	
Participant Oxygen Mask (circle): Position #1 <u>Q2 % & Temp Sensors</u> Position #2 Q2 Temp only	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>Same as ambient temp</u>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>5</u>	Date/Time <u>9 Jan 12 1300</u>
Test Number: <u>4</u>	
Participant Oxygen Mask (circle): <div><div>Position #1 O2 % & Temp Sensors</div><div><div>Position #2</div><div>O2 Temp only</div></div></div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <i>Temperature of O₂ was a little warm but nothing unreasonable</i>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>3</u>	Date/Time <u>10 Jan am</u>
Test Number: <u>5</u>	
Participant Oxygen Mask (circle): <div><div>Position #1 O2 % & Temp Sensors</div><div>Position #2 O2 Temp only</div></div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>5</u>	Date/Time <u>10 Jan am</u>
Test Number: <u>5</u>	
Participant Oxygen Mask (circle): <div><div>Position #1 O2 % & Temp Sensors</div><div><u>Position #2</u> <u>O2 Temp-only</u></div></div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>2</u>	Date/Time <u>10 Jan 64</u>
Test Number: <u>6</u> <u>Ht</u>	
Participant Oxygen Mask (circle): Position #1 <u>O2 % & Temp Sensors</u> Position #2 <u>O2 Temp only</u>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>Seemed warmer than previously experienced w/ cylinders</u>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>4</u>	Date/Time <u>16 Jan PM</u>
Test Number: <u>6</u> <u>ft</u>	
Participant Oxygen Mask (circle): <div><div>Position #1 O2 % & Temp Sensors</div><div><u>Position #2</u> <u>O2 Temp only</u></div></div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>A lot warmer than pressurized O2.</u>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>4</u>	Date/Time <u>11 Jan AM Run</u>
Test Number: <u>7</u> <div style="margin-left: 200px; text-align: center;"> Ventilator GL DISK Horizontal </div>	
Participant Oxygen Mask (circle): <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> Position #1 O2 % & Temp Sensors </div> <div style="text-align: center;"> Position #2 O2 Temp only </div> </div>	
Did you receive an acceptable breathing gas? (circle) Yes No <div style="text-align: center; margin-top: 20px;"> X </div> If No, note the altitude/s where you experienced any problems and describe the problem/s. <div style="text-align: right; margin-top: 10px;">N/A</div>	
Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No <div style="text-align: center; margin-top: 20px;"> X </div> If No, note the altitude/s where you experienced any problems and describe the problem/s. <div style="text-align: right; margin-top: 10px;">N/A</div>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes No <div style="text-align: center; margin-top: 20px;"> X </div> If Yes, note the altitude/s where you experienced symptoms and describe them. <div style="text-align: right; margin-top: 10px;">N/A</div>	
Ventilator tests: Did the ventilator appear to operate normally? (circle) <u>Yes</u> No N/A If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>3</u>	Date/Time <u>11 Jan am</u>
Test Number: <u>7</u> Vent GL 15K Horizontal	
Participant Oxygen Mask (circle): Position #1 O2 % & Temp Sensors	Position #2 O2 Temp only
Did you receive an acceptable breathing gas? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes No If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No N/A If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>2</u>	Date/Time <u>11 Jan 1430</u>
Test Number: <u>8</u> <u>Cold</u> <u>-40</u> <u>Horizon</u>	
Participant Oxygen Mask (circle): Position #1 <u>O2 % & Temp Sensors</u> Position #2 <u>O2 Temp only</u>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems. <u>N/A</u>	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>1</u>	Date/Time <u>11 Jan 1430</u>
Test Number: <u>8</u> <u>Cold - 40</u> <u>Horizon</u>	
Participant Oxygen Mask (circle): Position #1 X Position #2 <u>O</u> O2 % & Temp Sensors O2 Temp only	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>Was at same temp as the chamber</u>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems. <u>X</u> <u>N/A</u>	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>2</u>	Date/Time <u>125an am</u>
Test Number: <u>9</u> <i>Ventilator GL +15K</i> <i>Vertical</i>	
Participant Oxygen Mask (circle): Position #1 O2 % & Temp Sensors	Position #2 O2 Temp only
Did you receive an acceptable breathing gas? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes No If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) <u>Yes</u> No N/A If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>4</u>	Date/Time <u>12 Jan 00</u>
Test Number: <u>9</u> Ventilator GL + 15K Vertical	
Participant Oxygen Mask (circle): <div>Position #1 Position #2</div> <div>O2 % & Temp Sensors O2 Temp only</div>	
Did you receive an acceptable breathing gas? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes No If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No N/A If No, note any problems.	

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>1</u>	Date/Time <u>11 Jan PM</u>
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Test Number: <u>10</u> - 40 F Vertical

Participant Oxygen Mask (circle):
Position #1 Position #2
O2 % & Temp Sensors O2 Temp only

Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No
If No, note the altitude/s where you experienced any problems and describe the problem/s.

Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No
If No, note the altitude/s where you experienced any problems and describe the problem/s.

Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u>
If Yes, note the altitude/s where you experienced symptoms and describe them.

Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u>
If No, note any problems.

N/A

ATTACHMENT

MMOS QUESTIONNAIRE

Manned Testing of the Mounted Medical Oxygen System

Participant Mask Number: <u>5</u>	Date/Time <u>11 Jan PM</u>
Test Number: <u>10</u> <u>-40 f</u> <u>Vertical</u>	
Participant Oxygen Mask (circle): <div style="display: flex; justify-content: space-around;"><div style="text-align: center;"><u>Position #1</u> <u>O2 % & Temp Sensors</u></div><div style="text-align: center;">Position #2 O2 Temp only</div></div>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>O₂ was slightly colder but no issue</u>	
Did you experience any symptoms while breathing on the MMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No <u>N/A</u> If No, note any problems. <u>N/A</u>	

ATTACHMENT

APPENDIX D: DMOS Unmanned Data

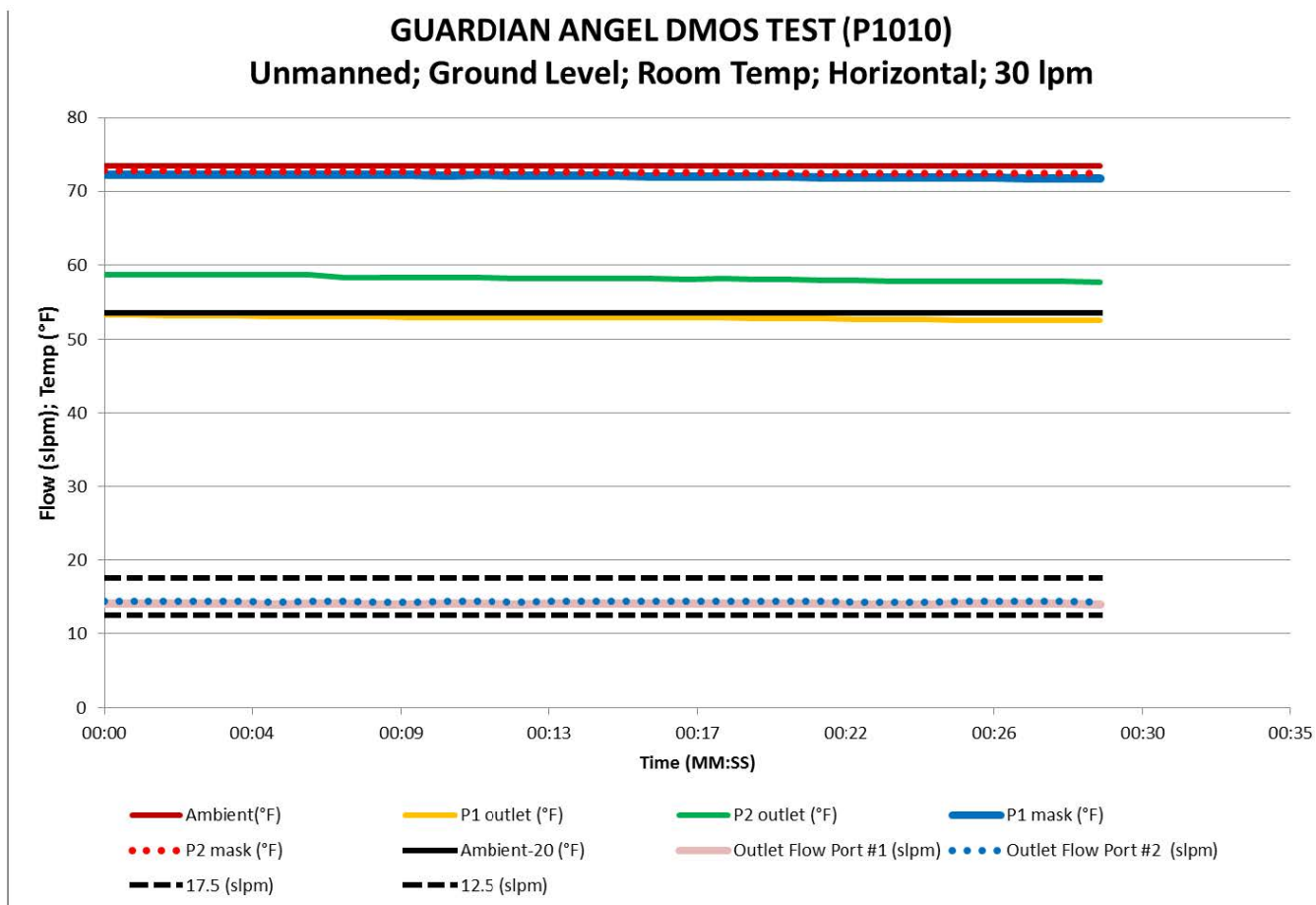


Figure D-1

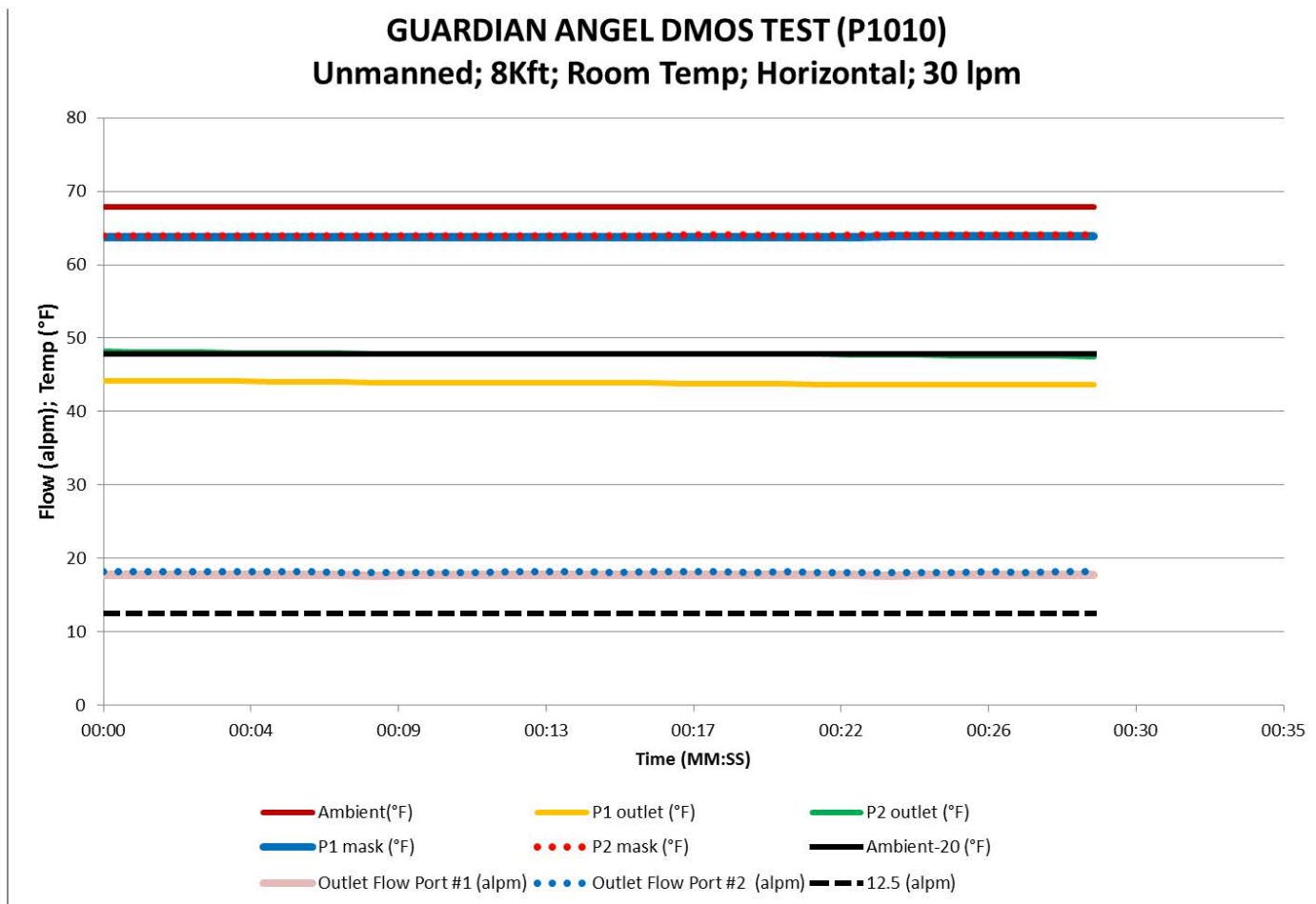


Figure D-2

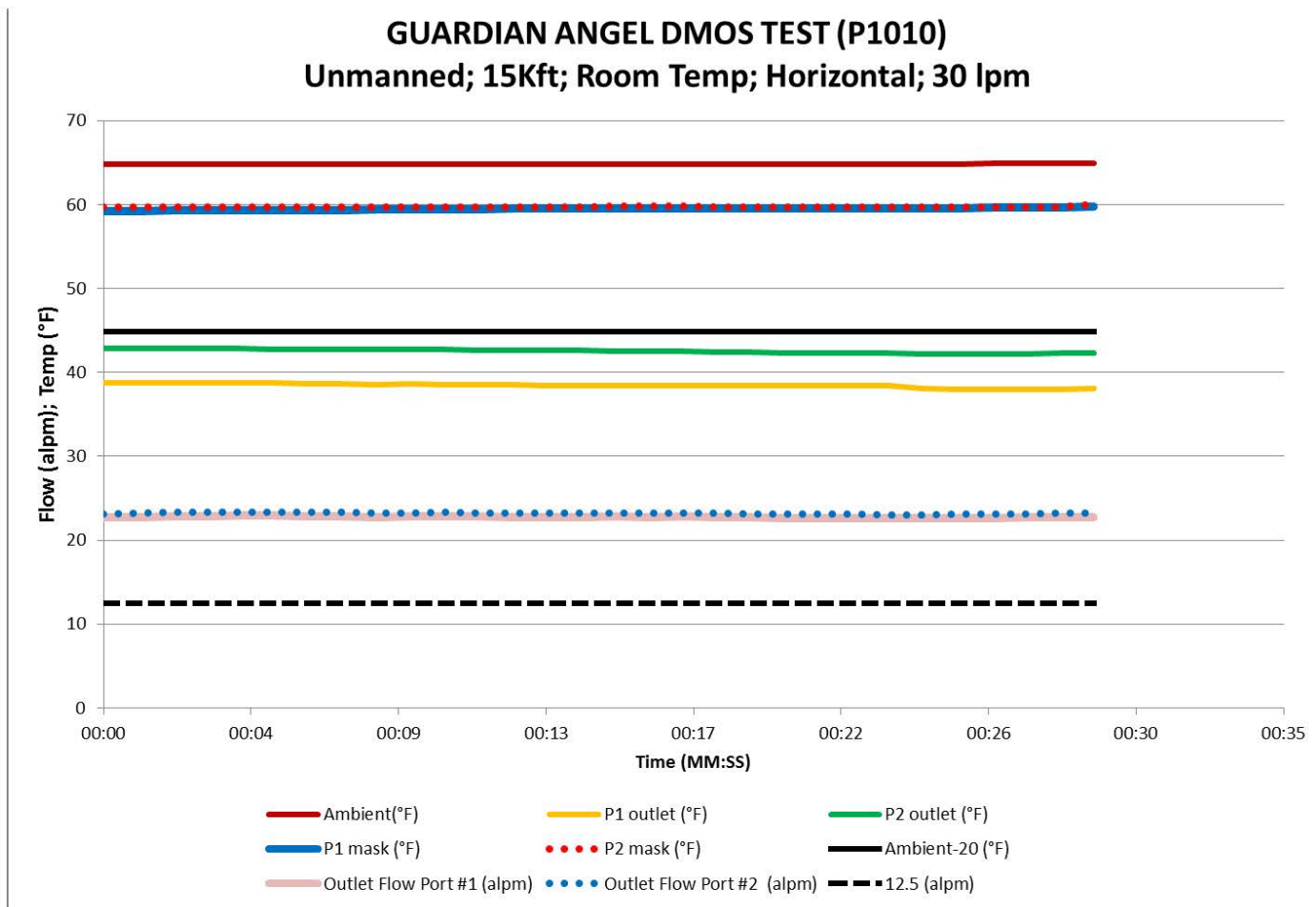


Figure D-3

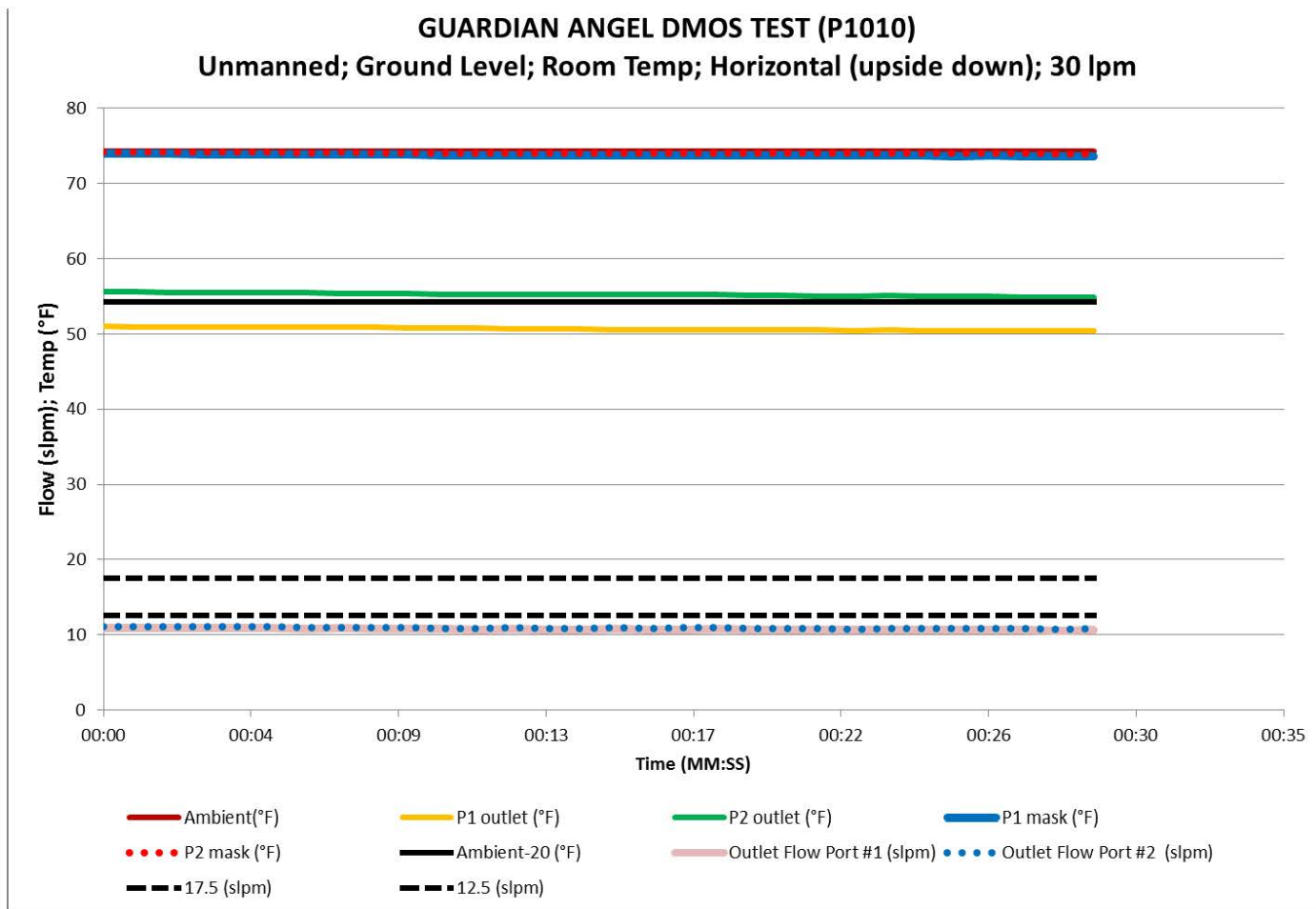


Figure D-4

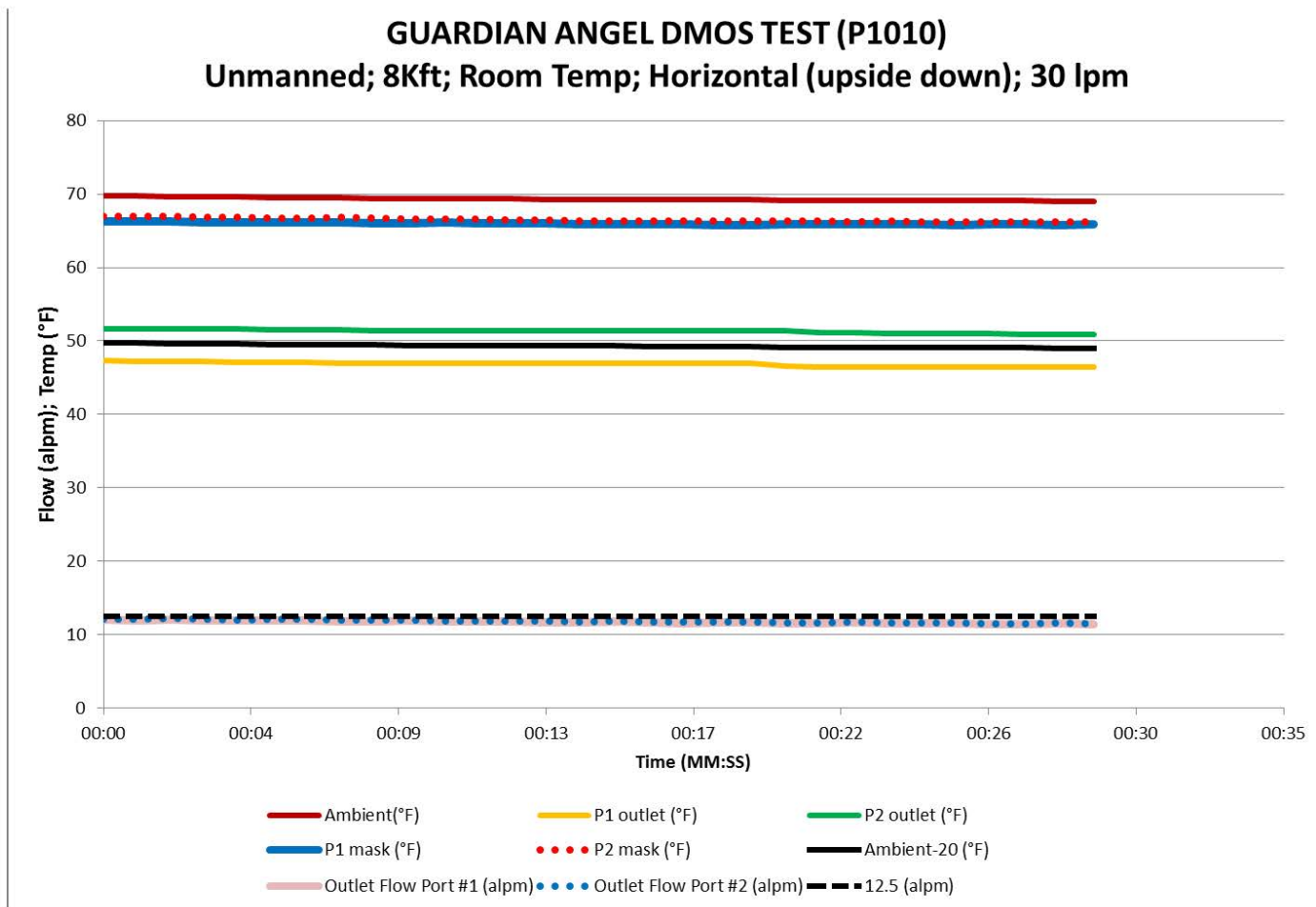


Figure D-5

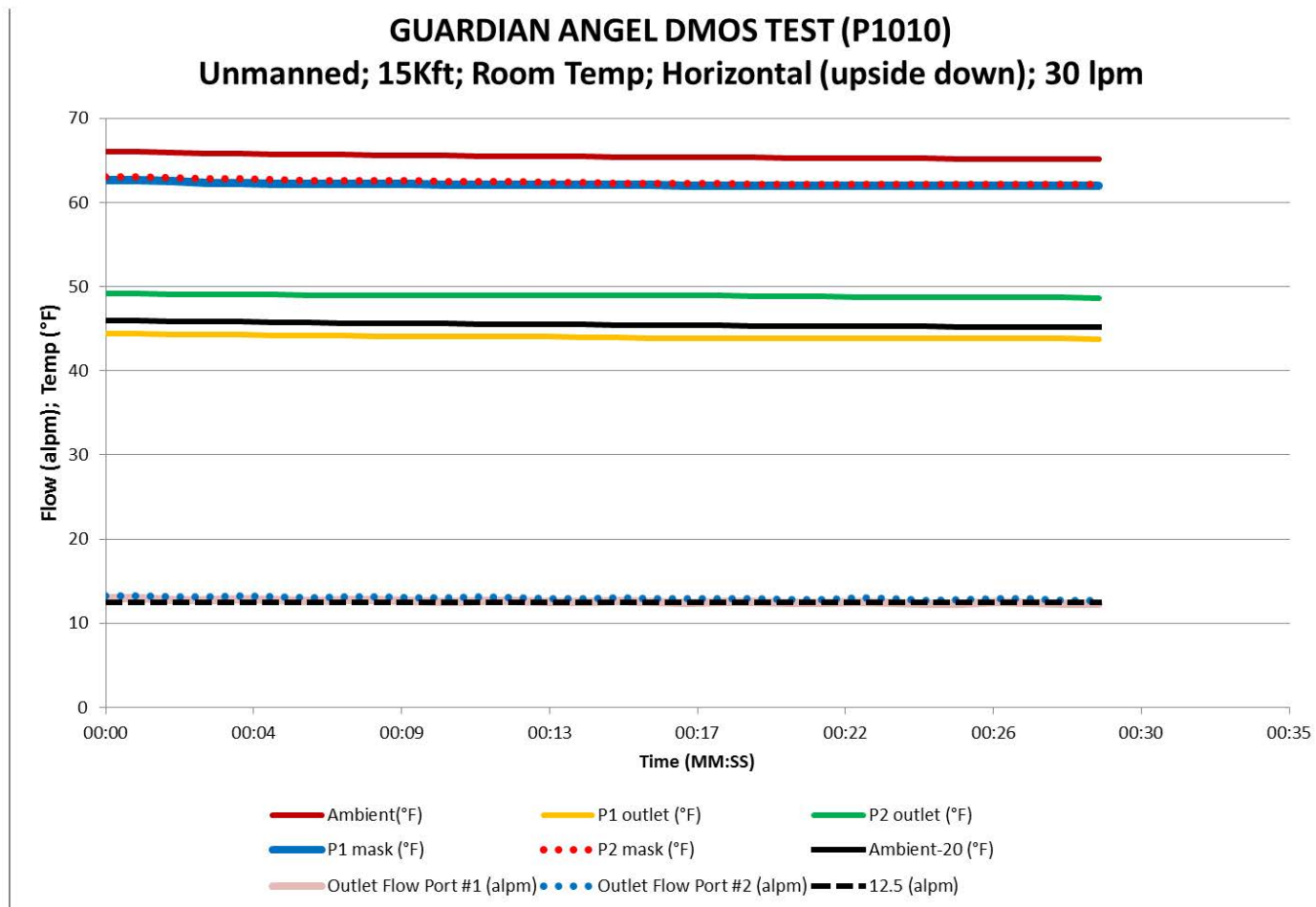


Figure D-6

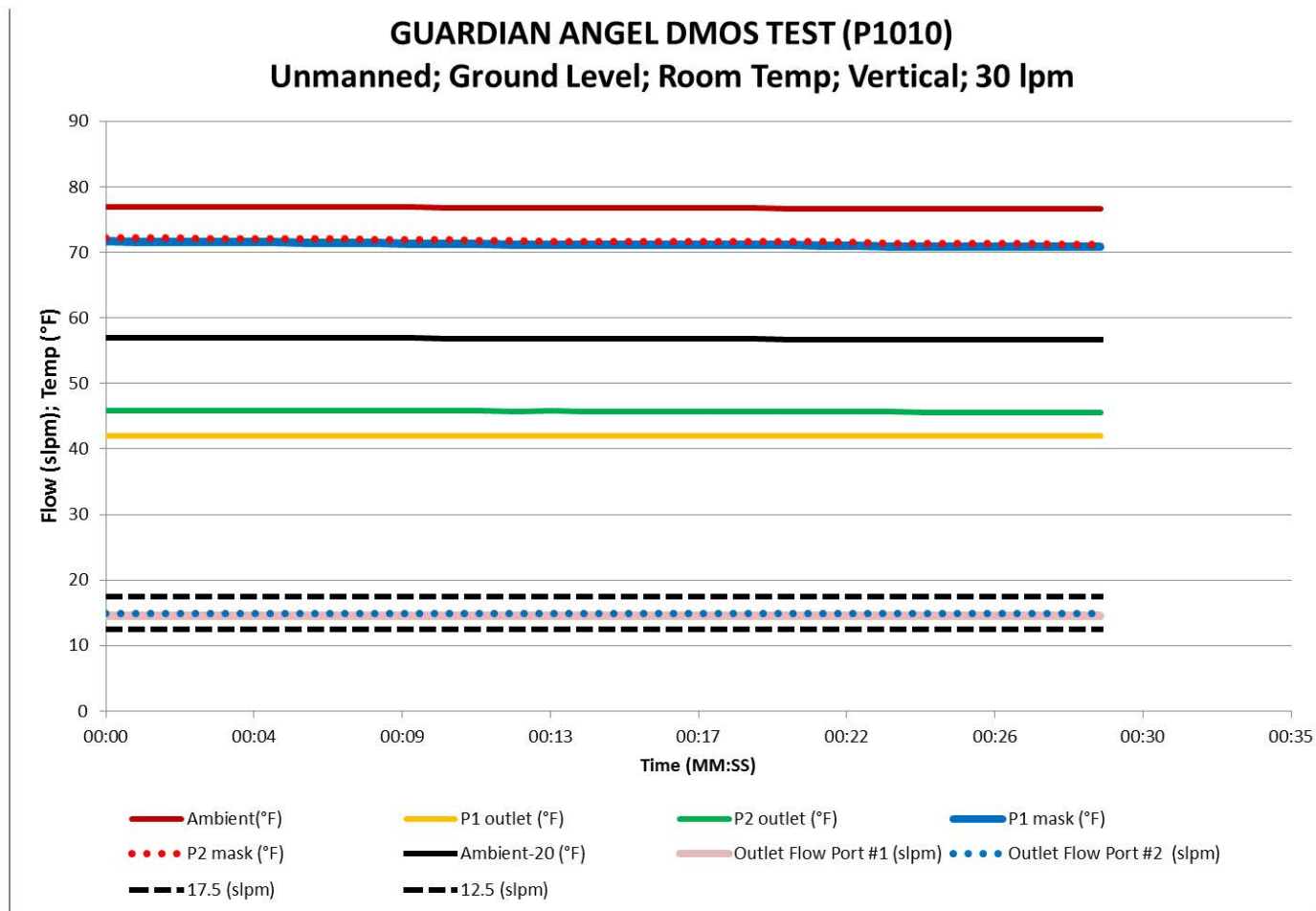


Figure D-7

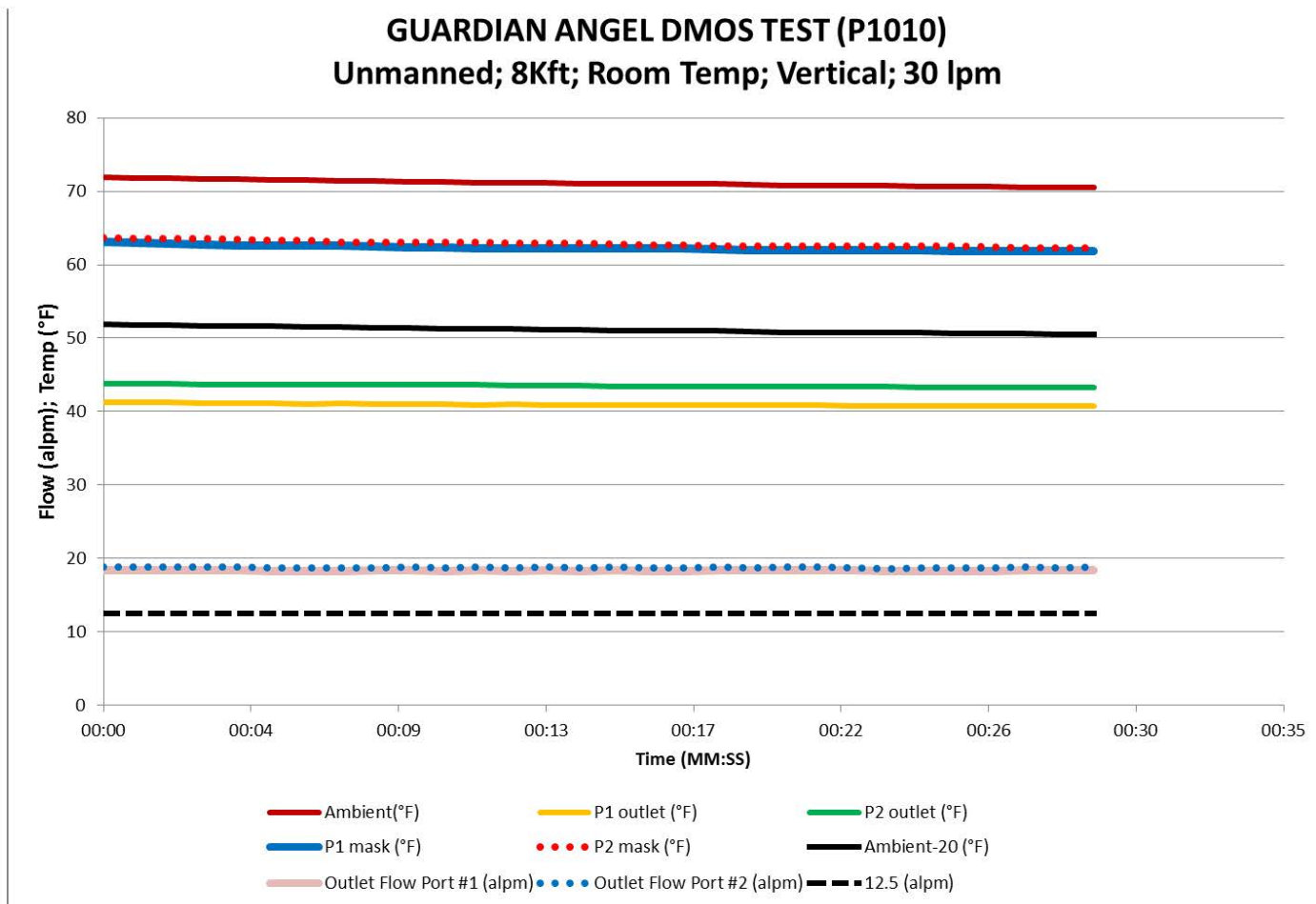


Figure D-8

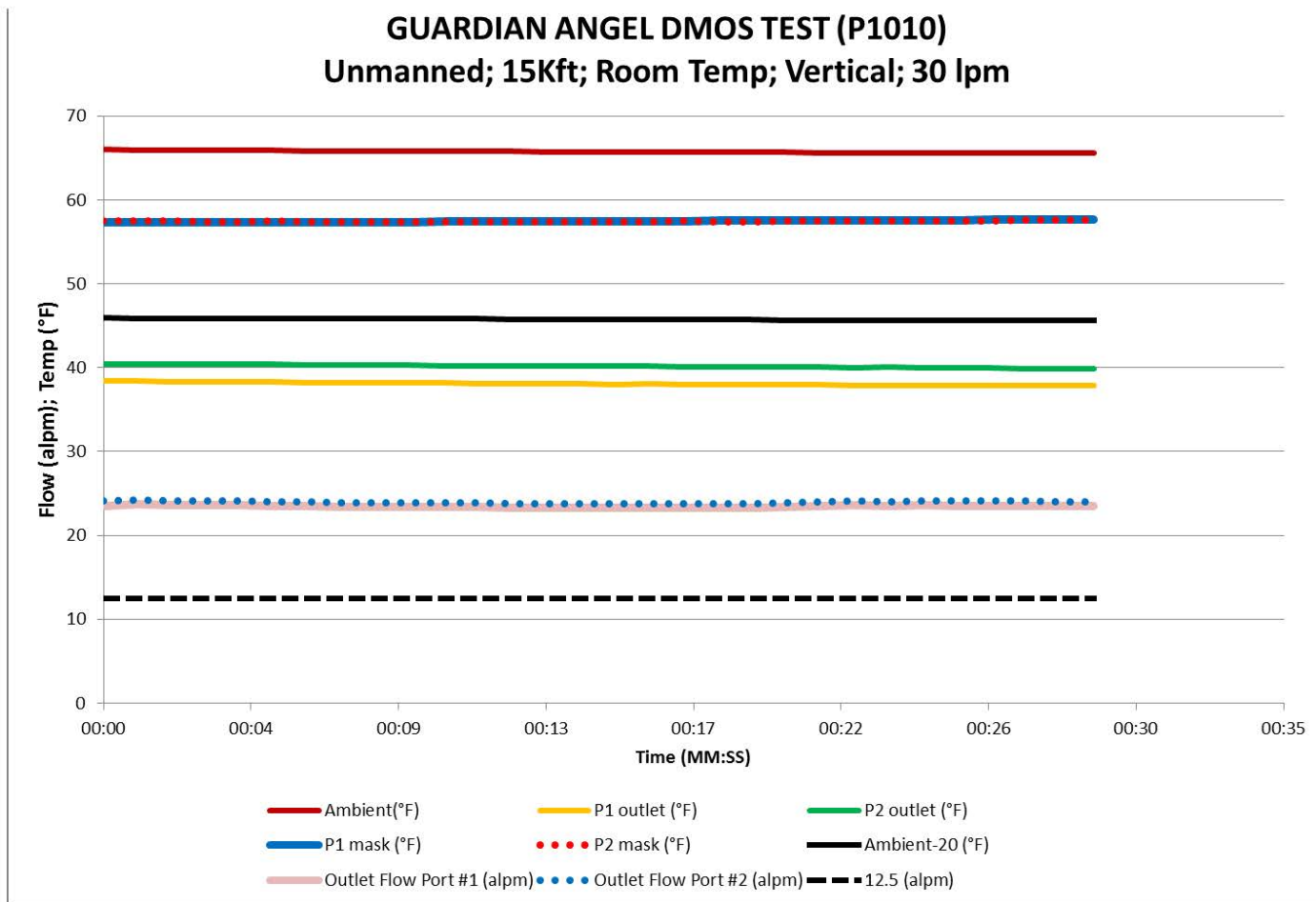


Figure D-9

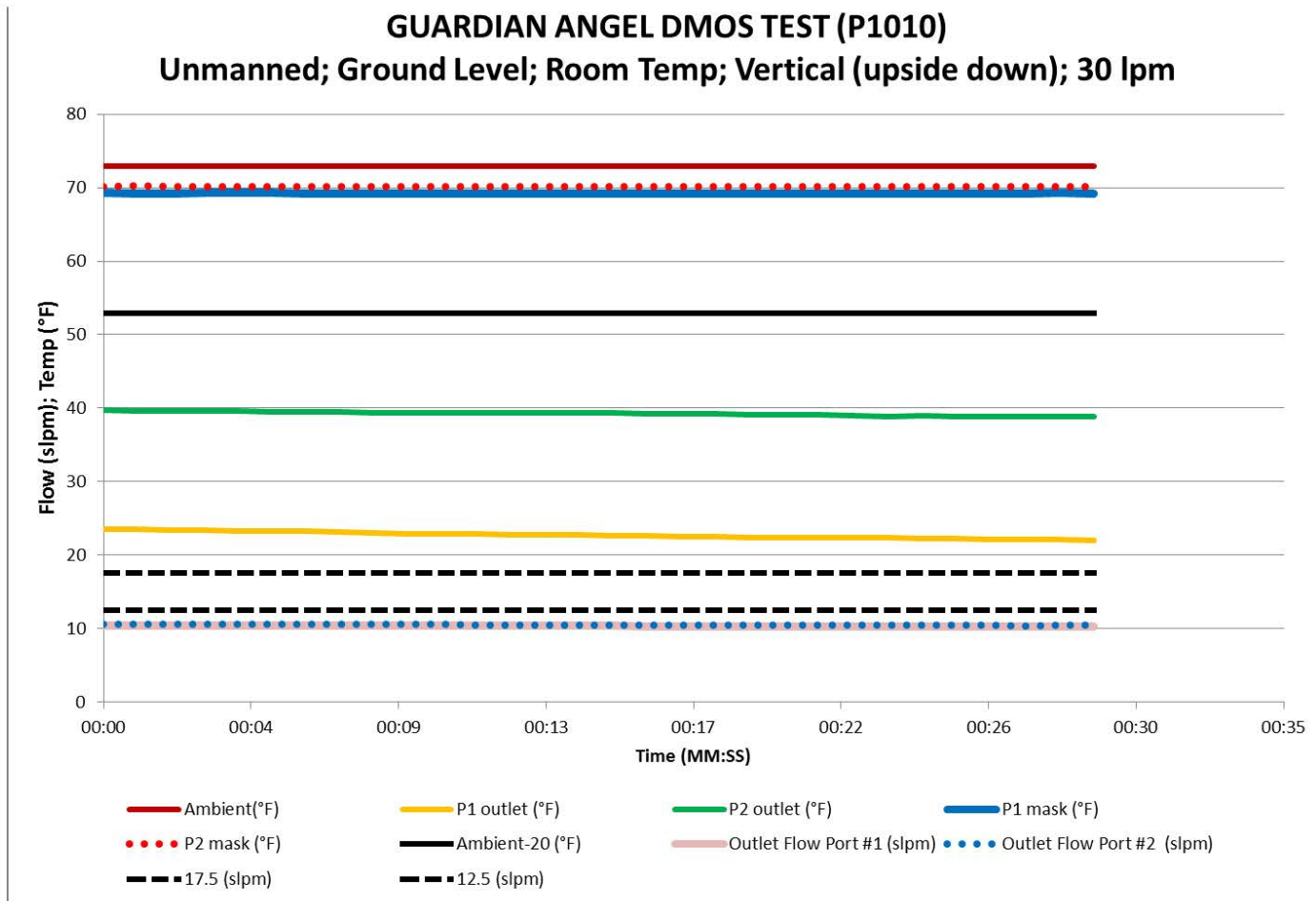


Figure D-10

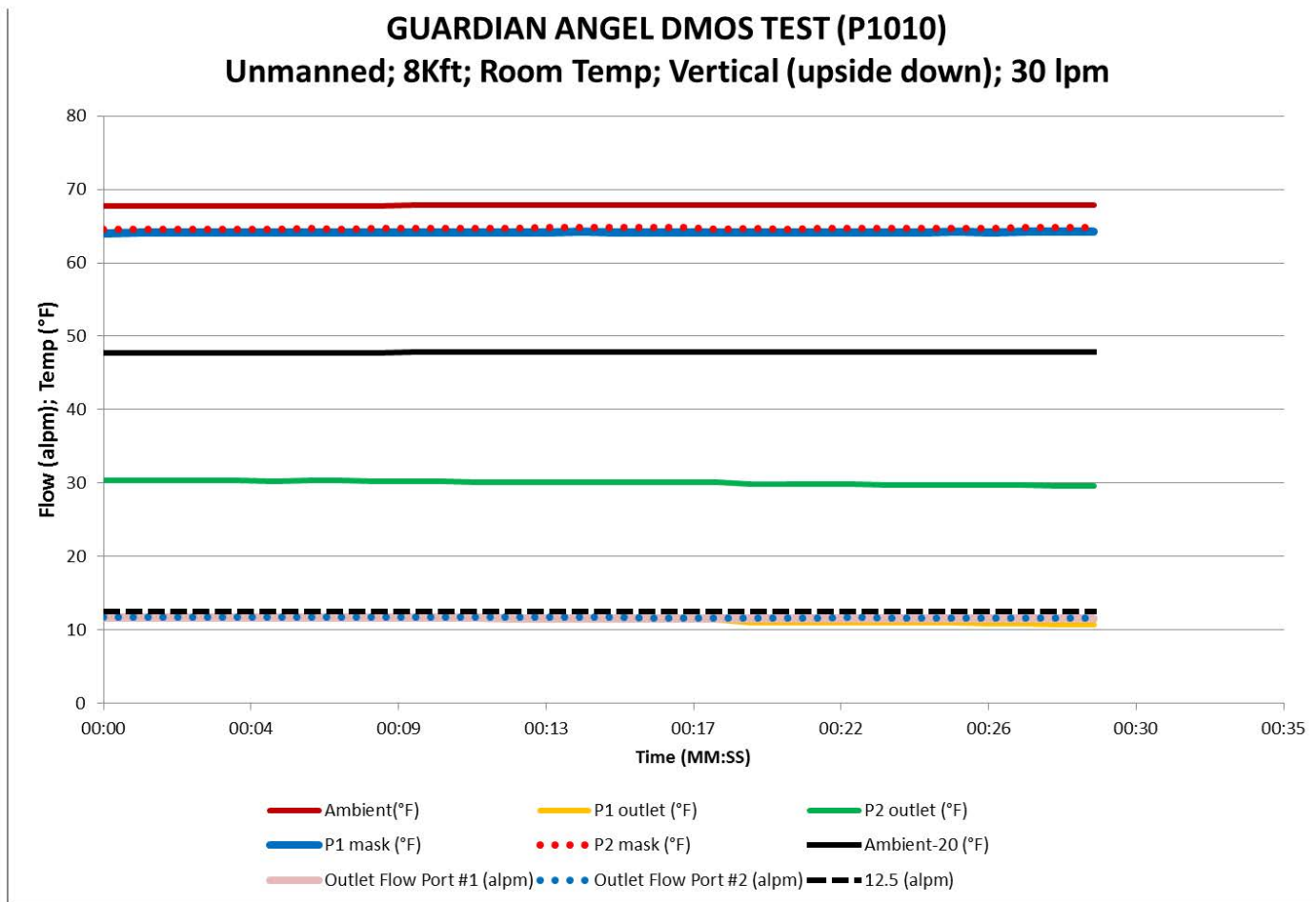


Figure D-11

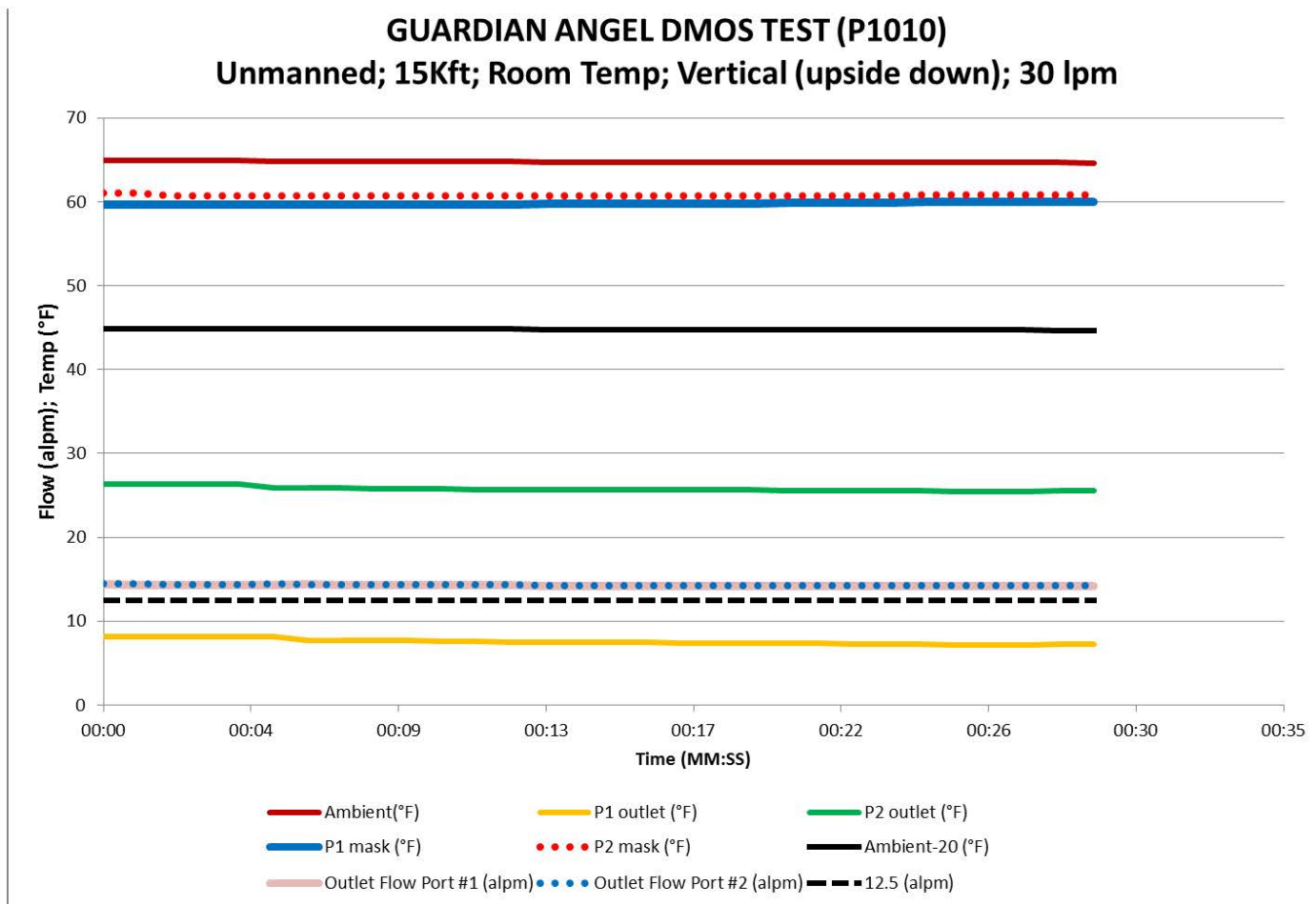


Figure D-12

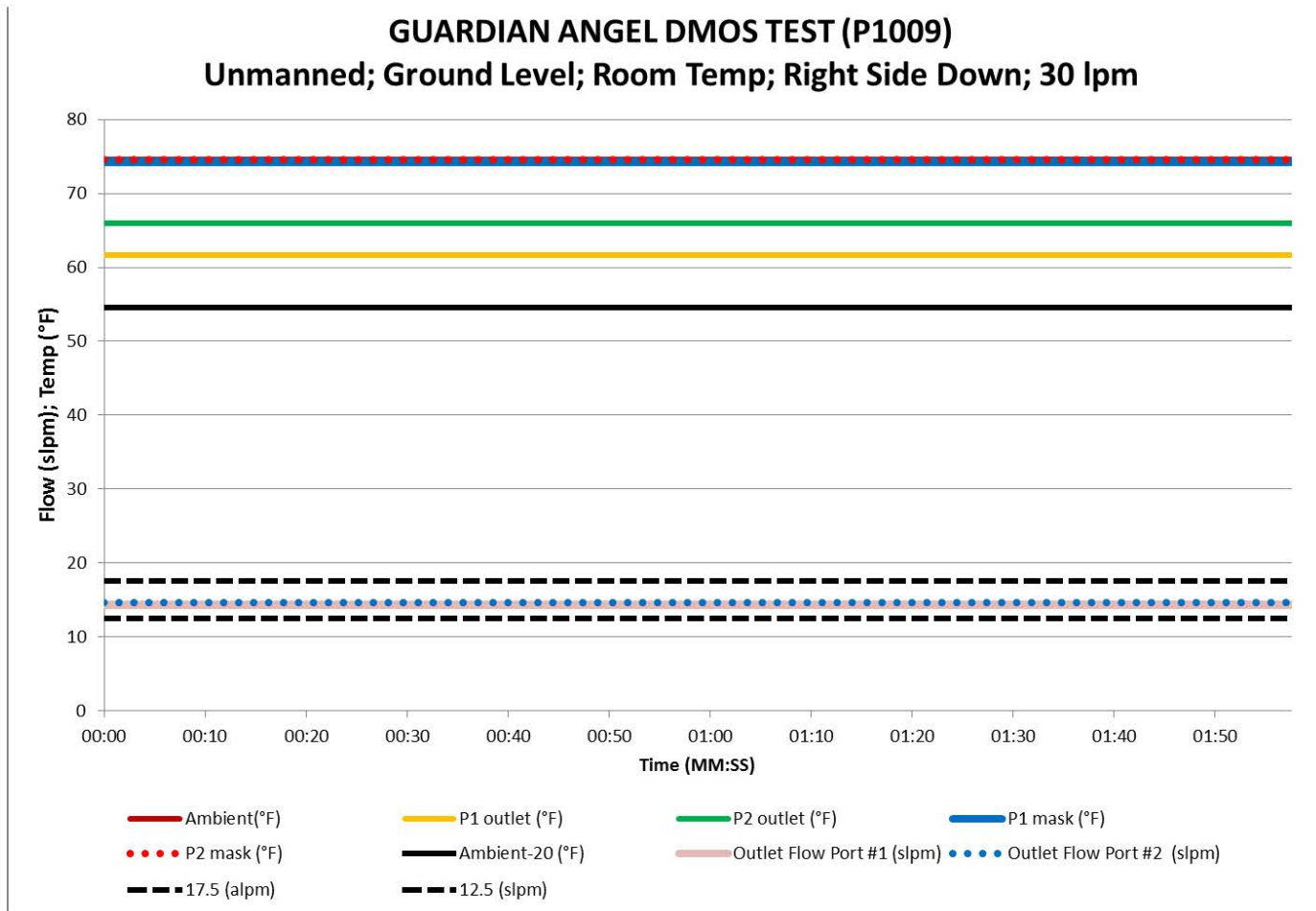


Figure D-13

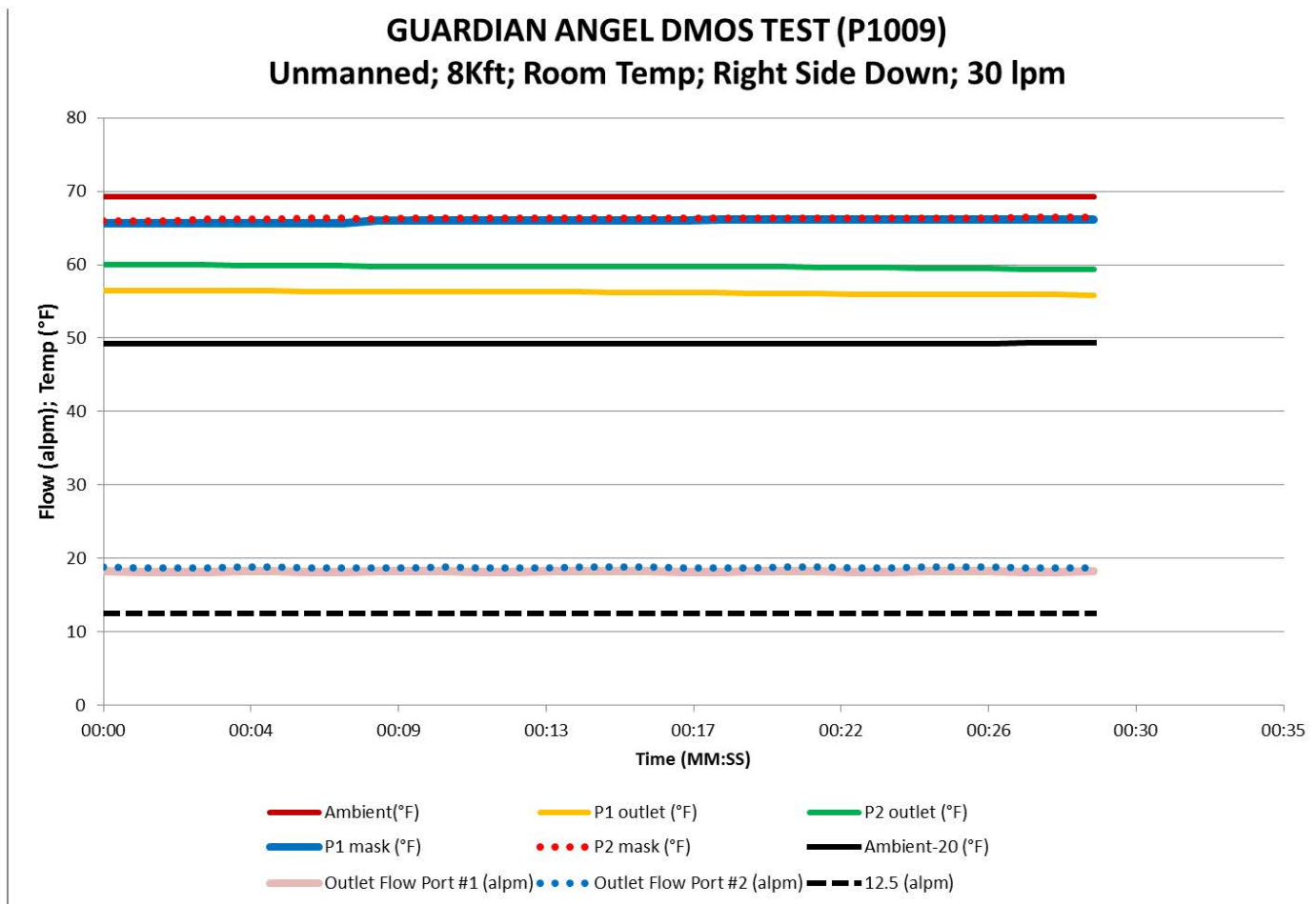


Figure D-14

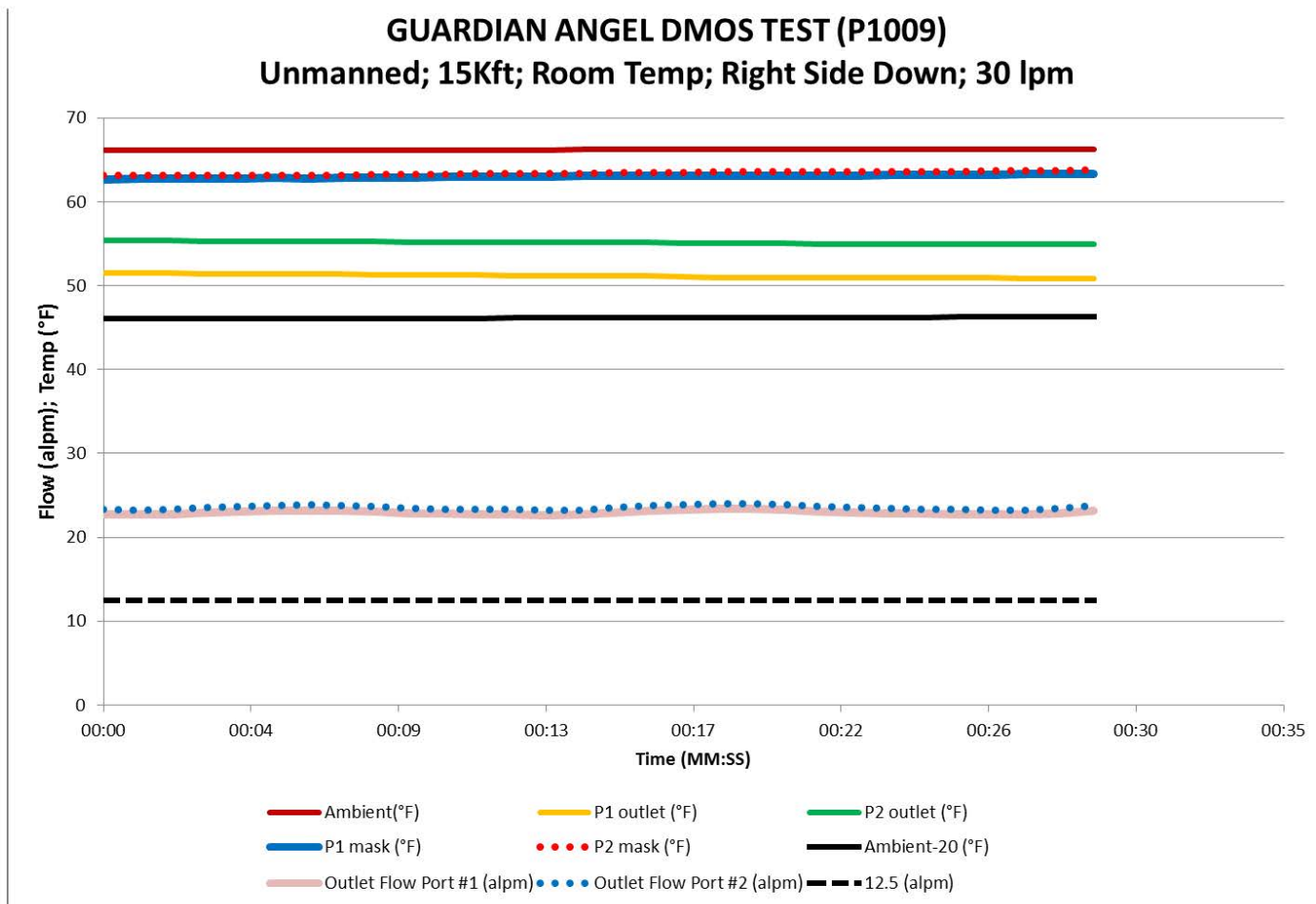


Figure D-15

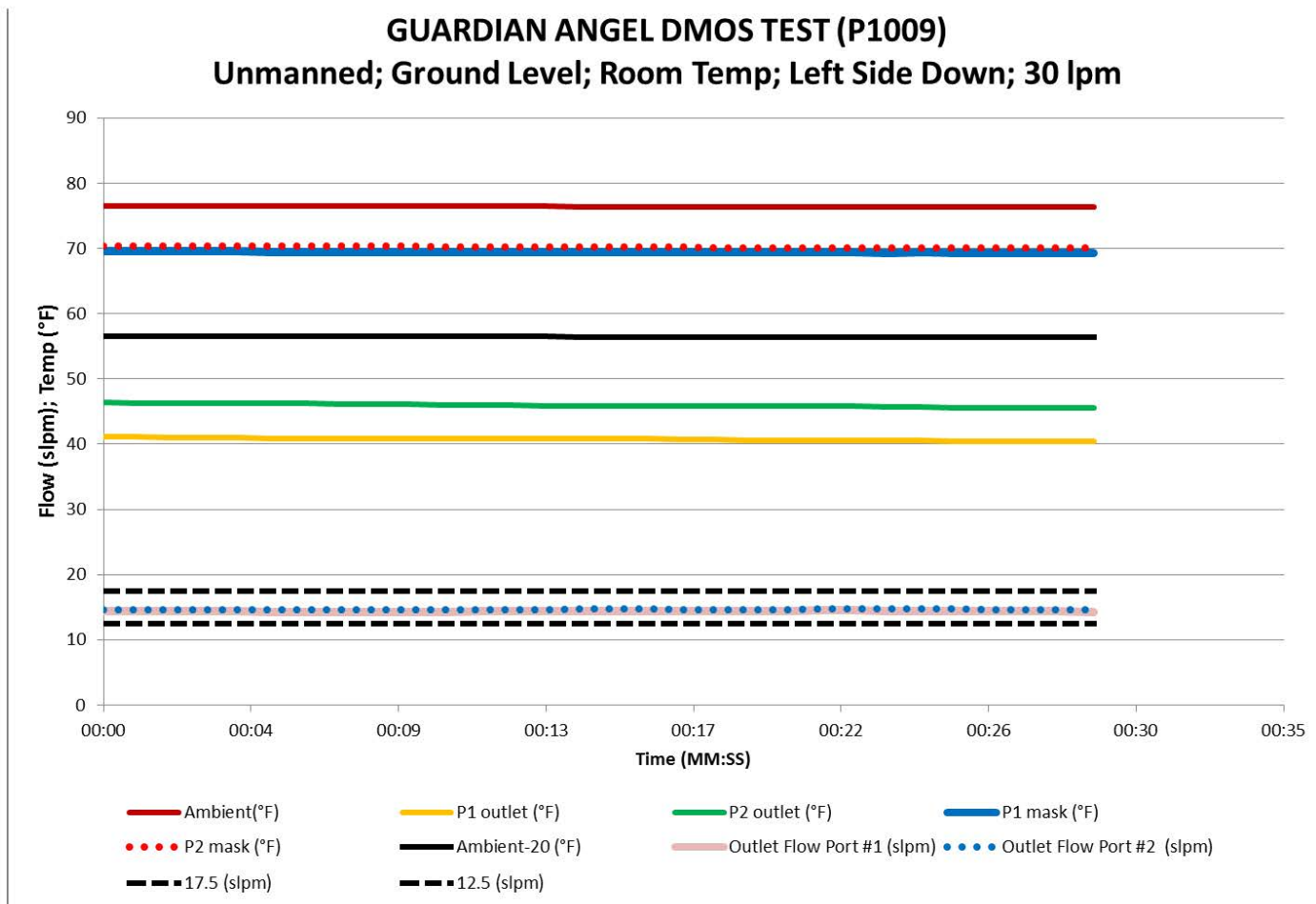


Figure D-16

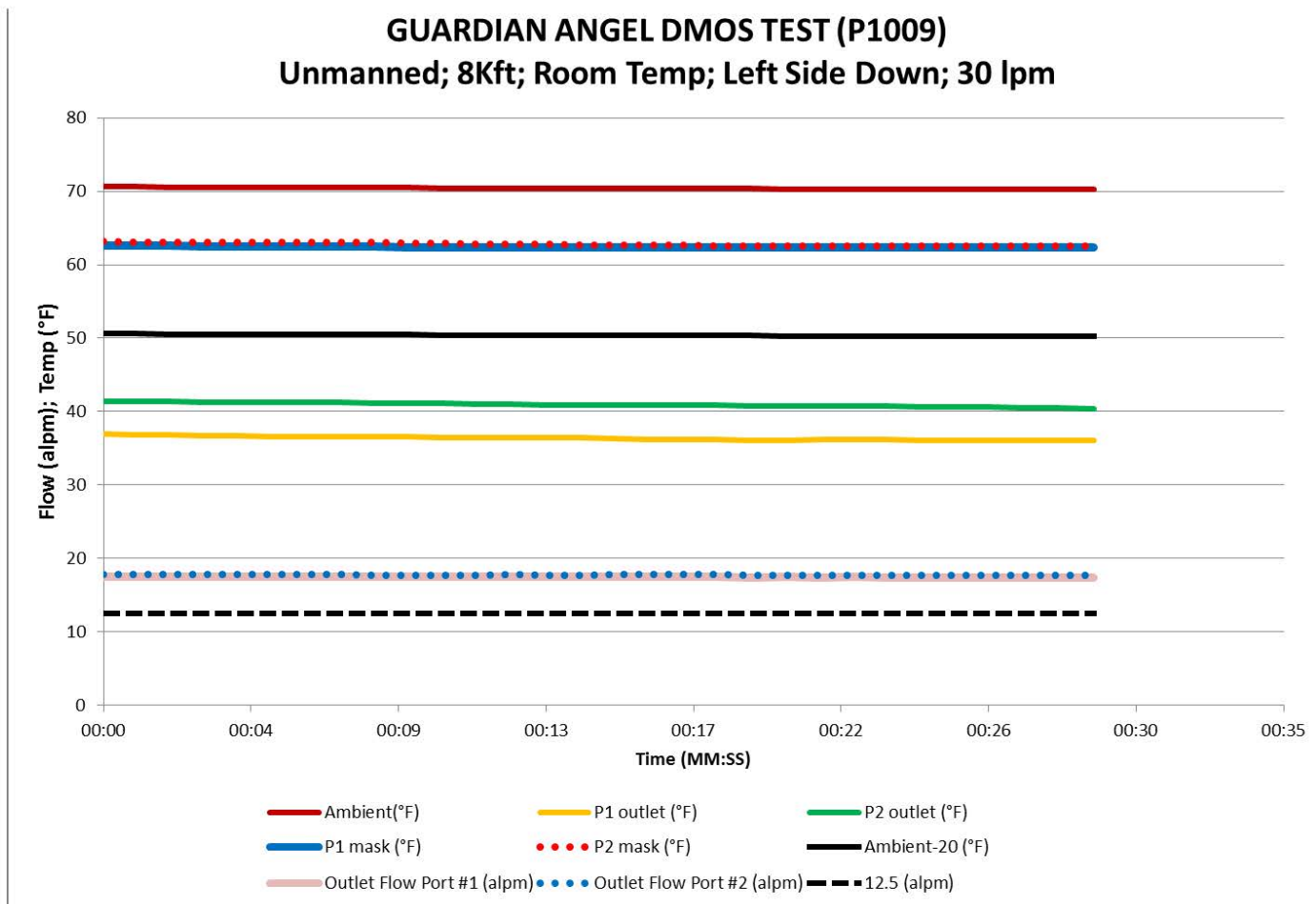


Figure D-17

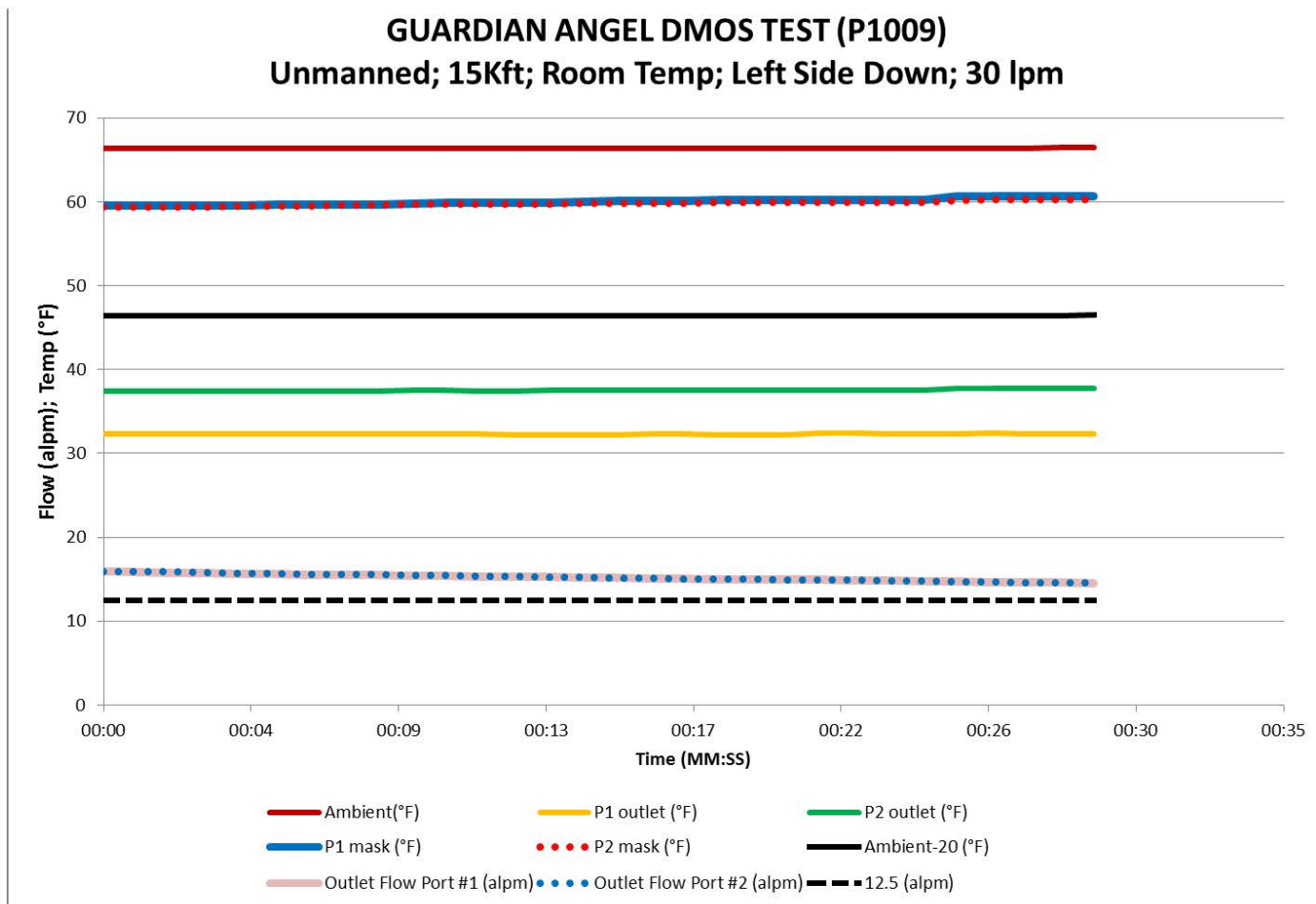


Figure D-18

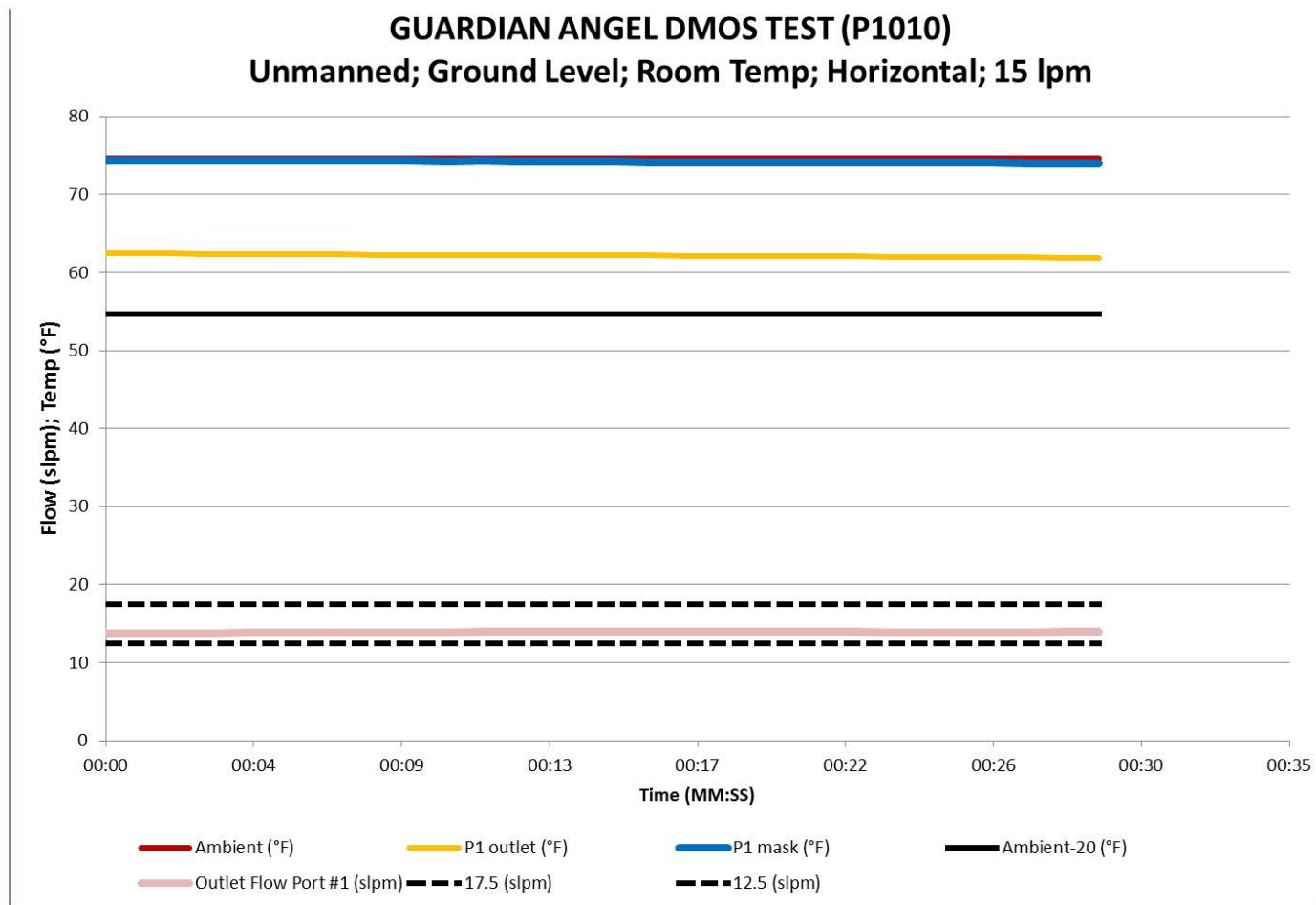


Figure D-19

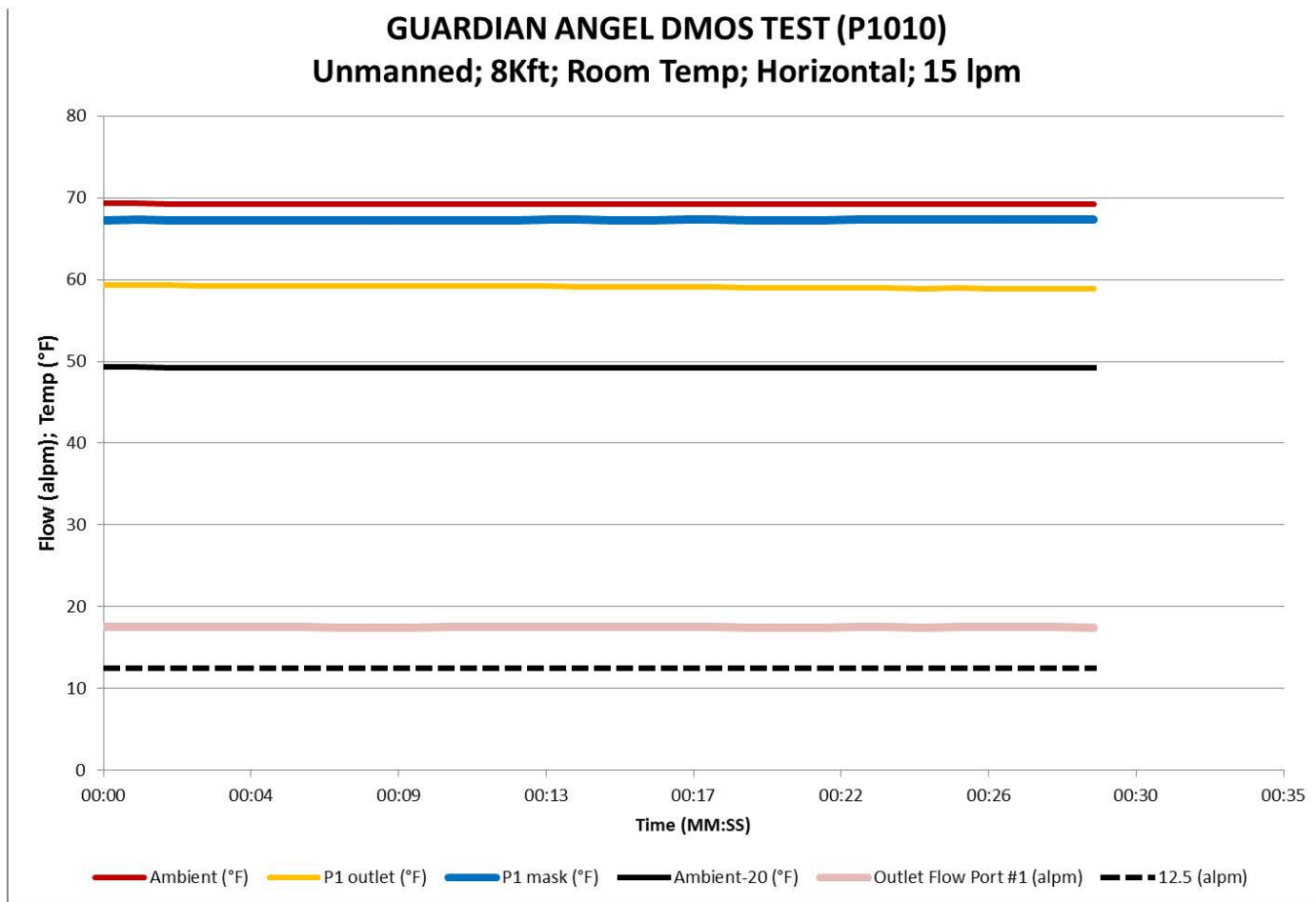


Figure D-20

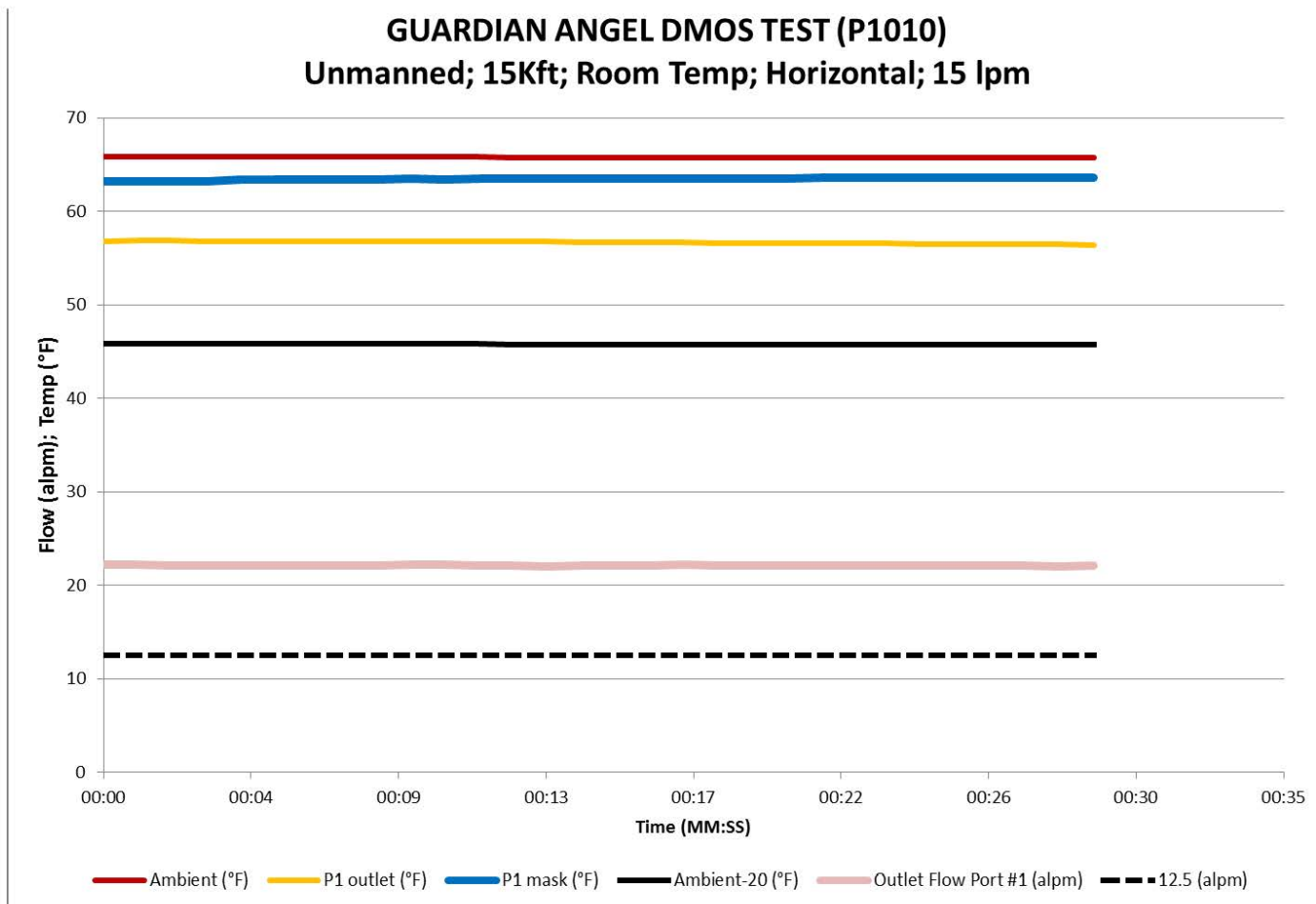


Figure D-21

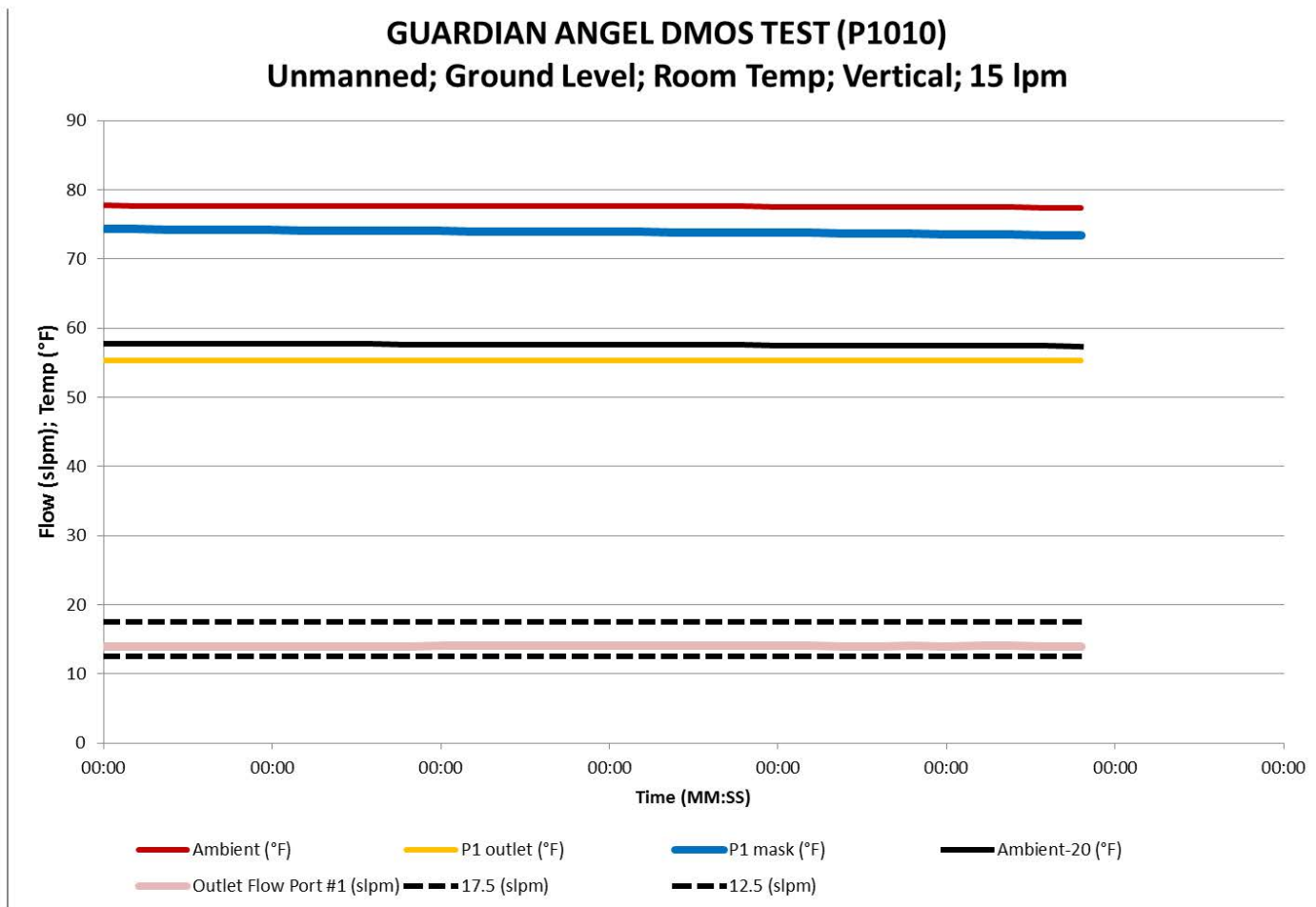


Figure D-22

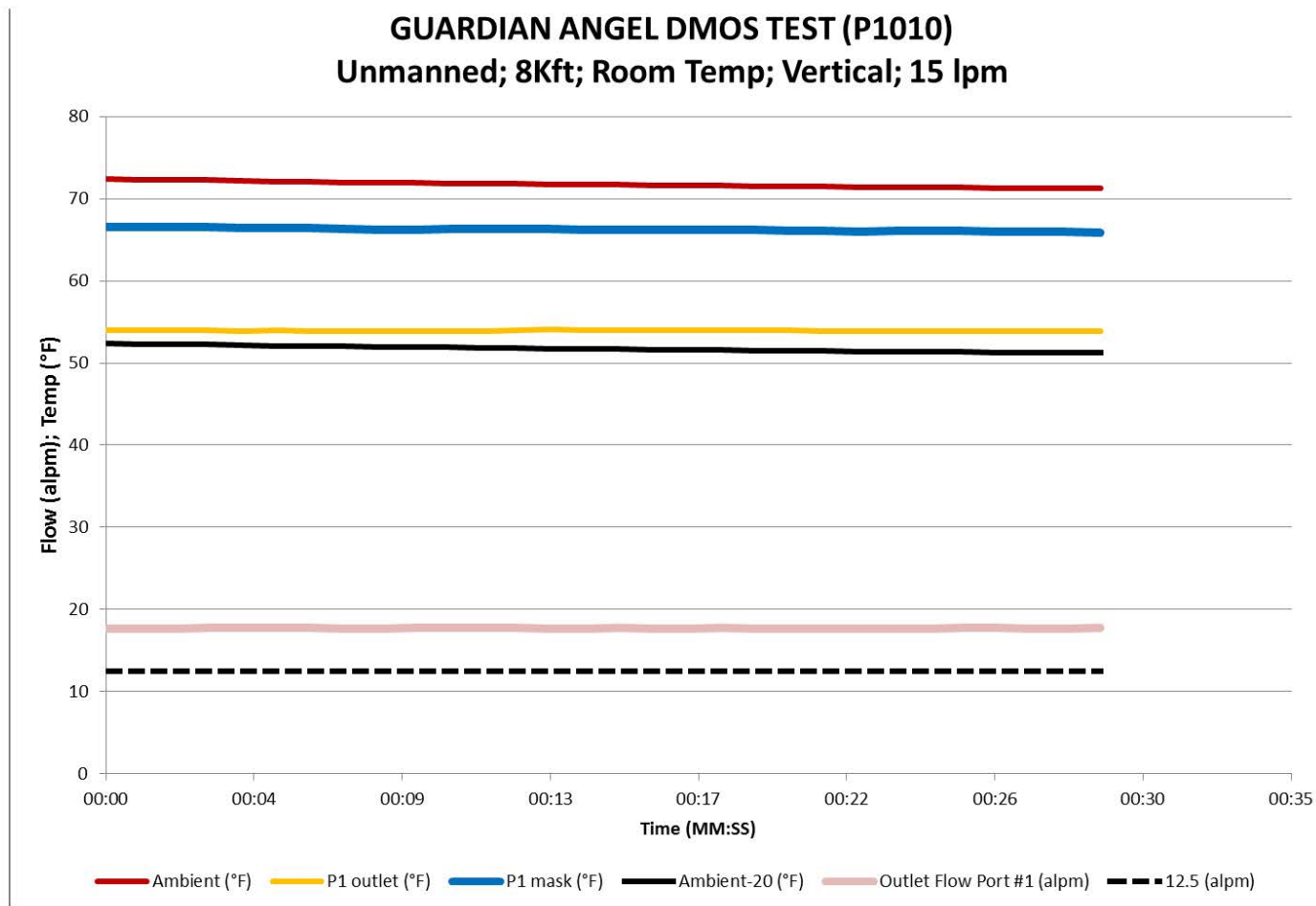


Figure D-23

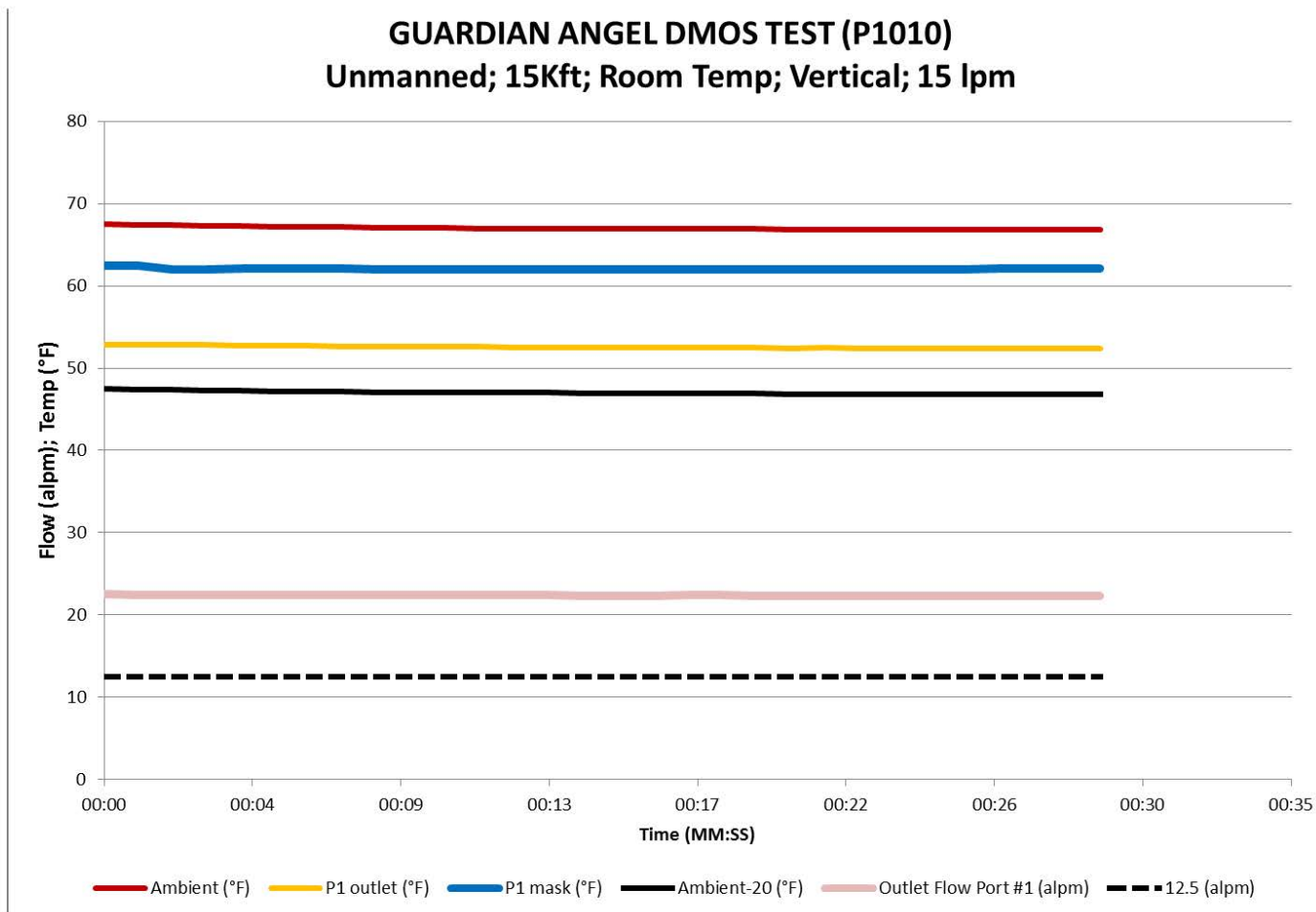


Figure D-24

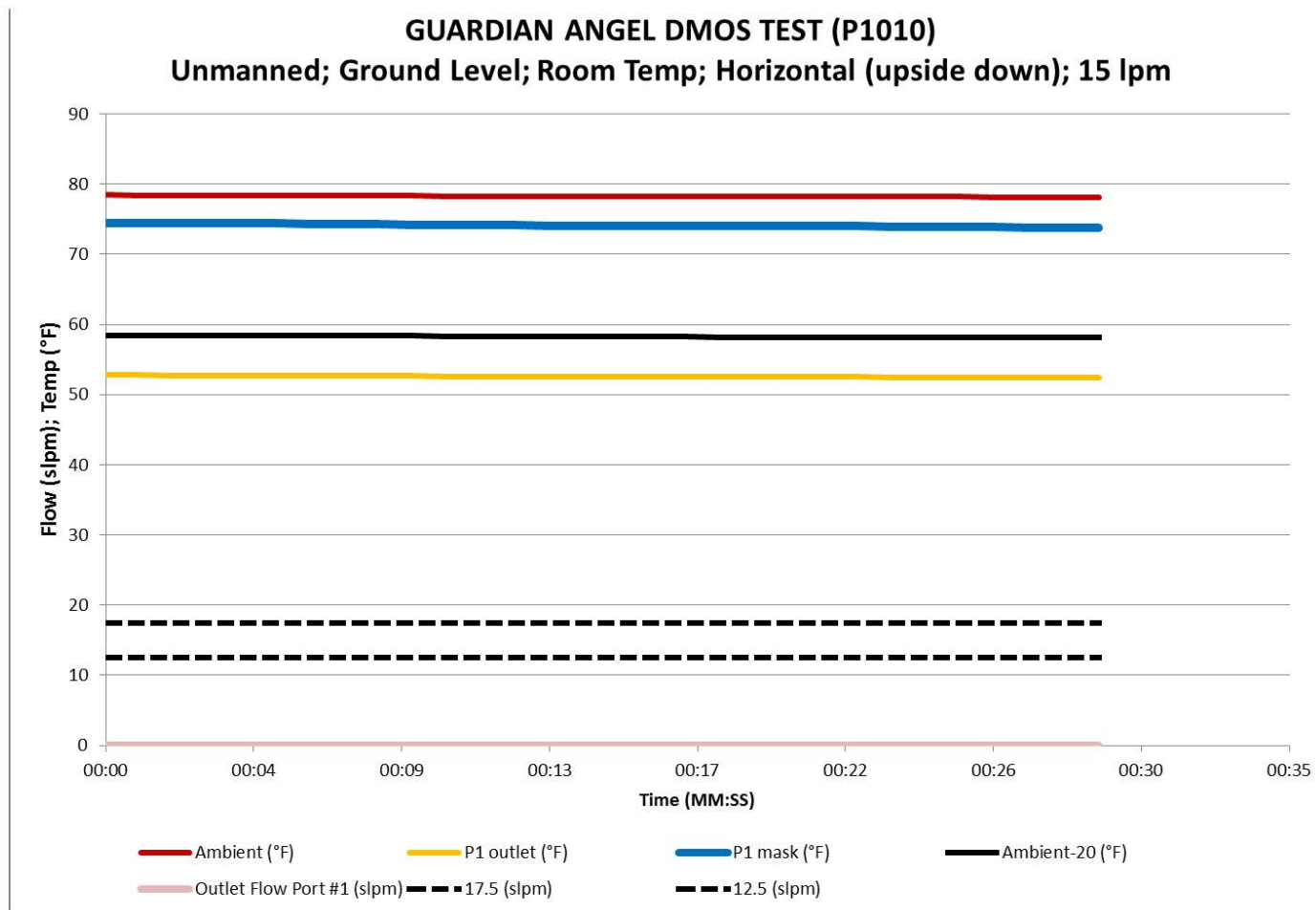


Figure D-25

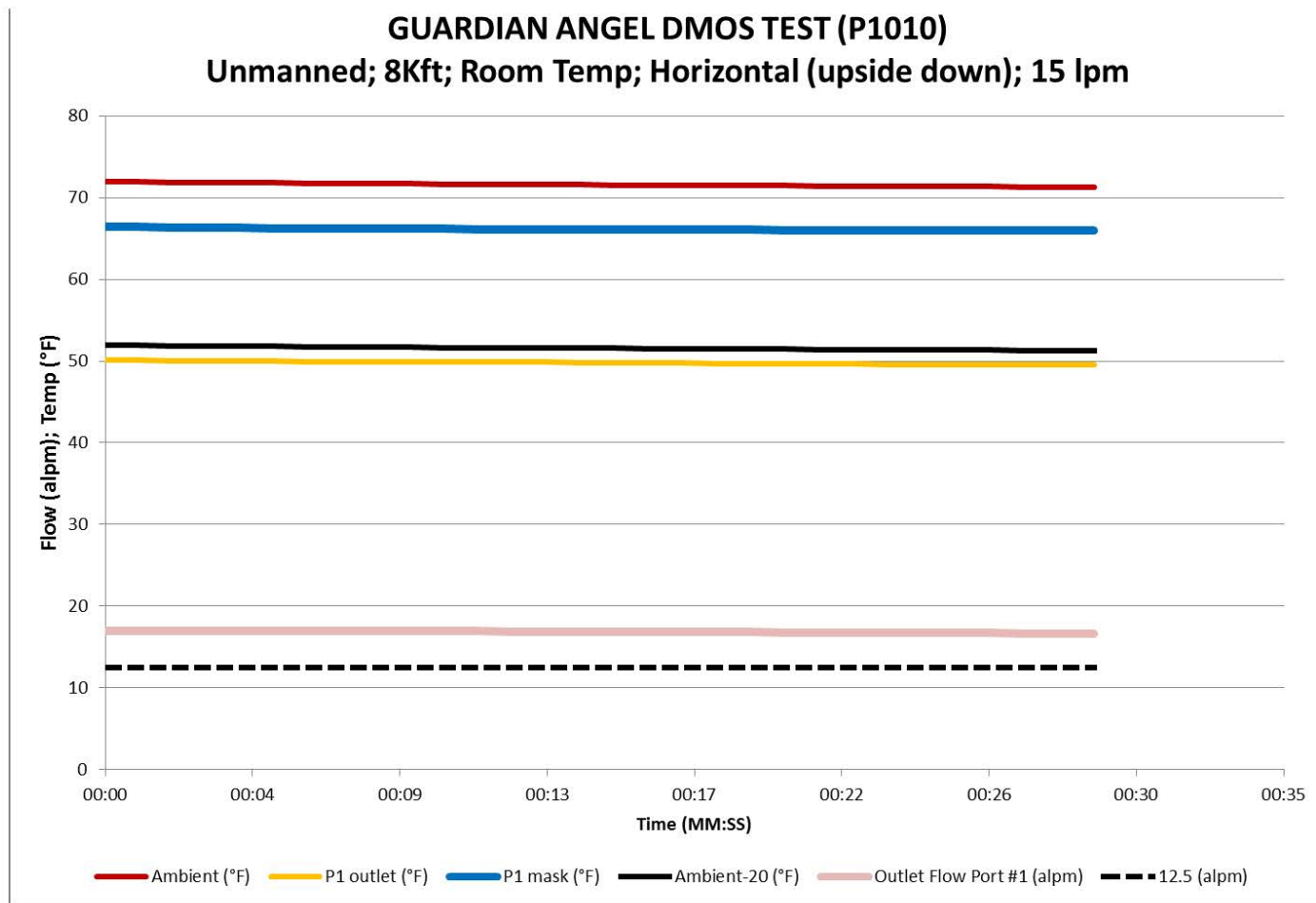


Figure D-26

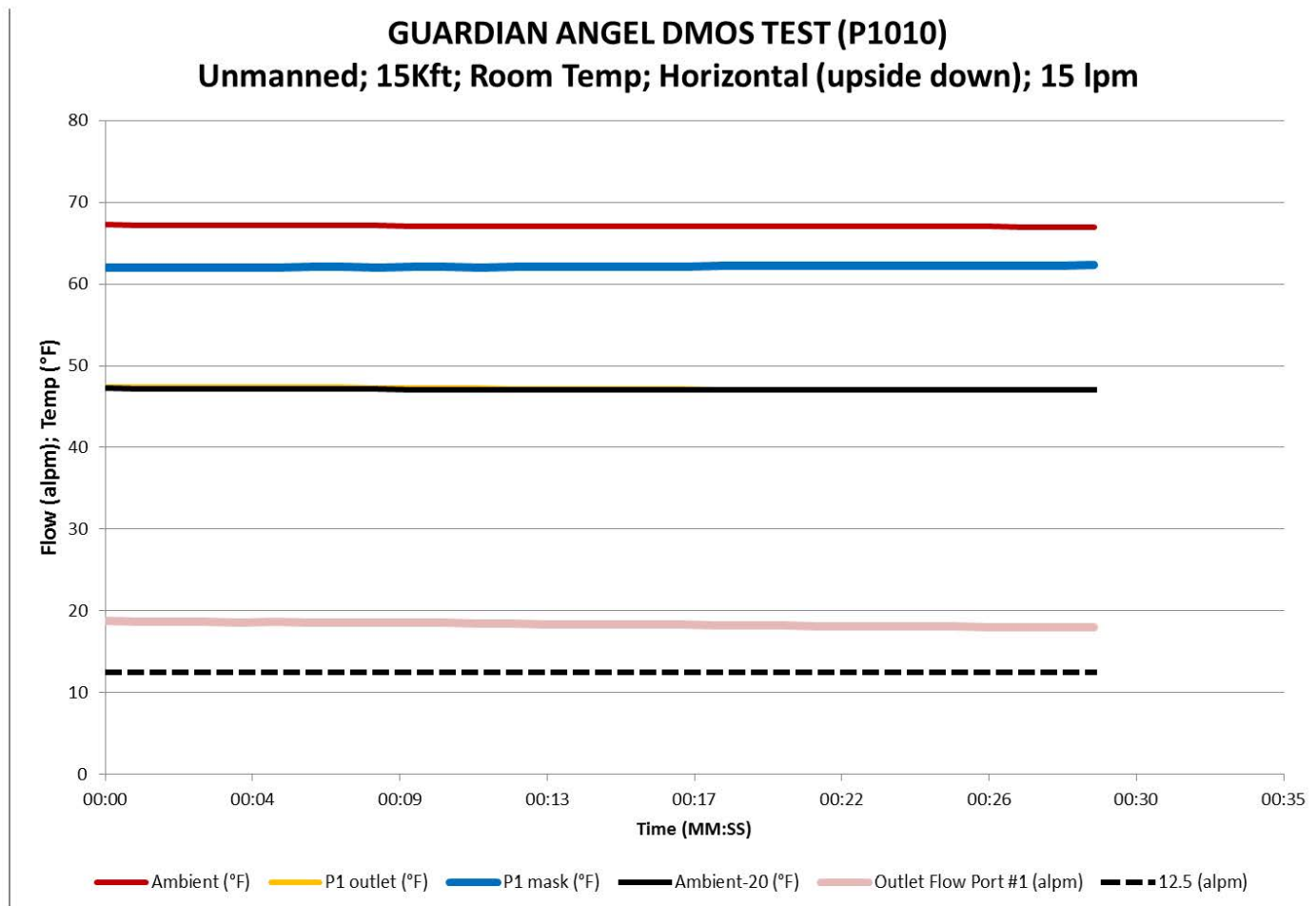


Figure D-27

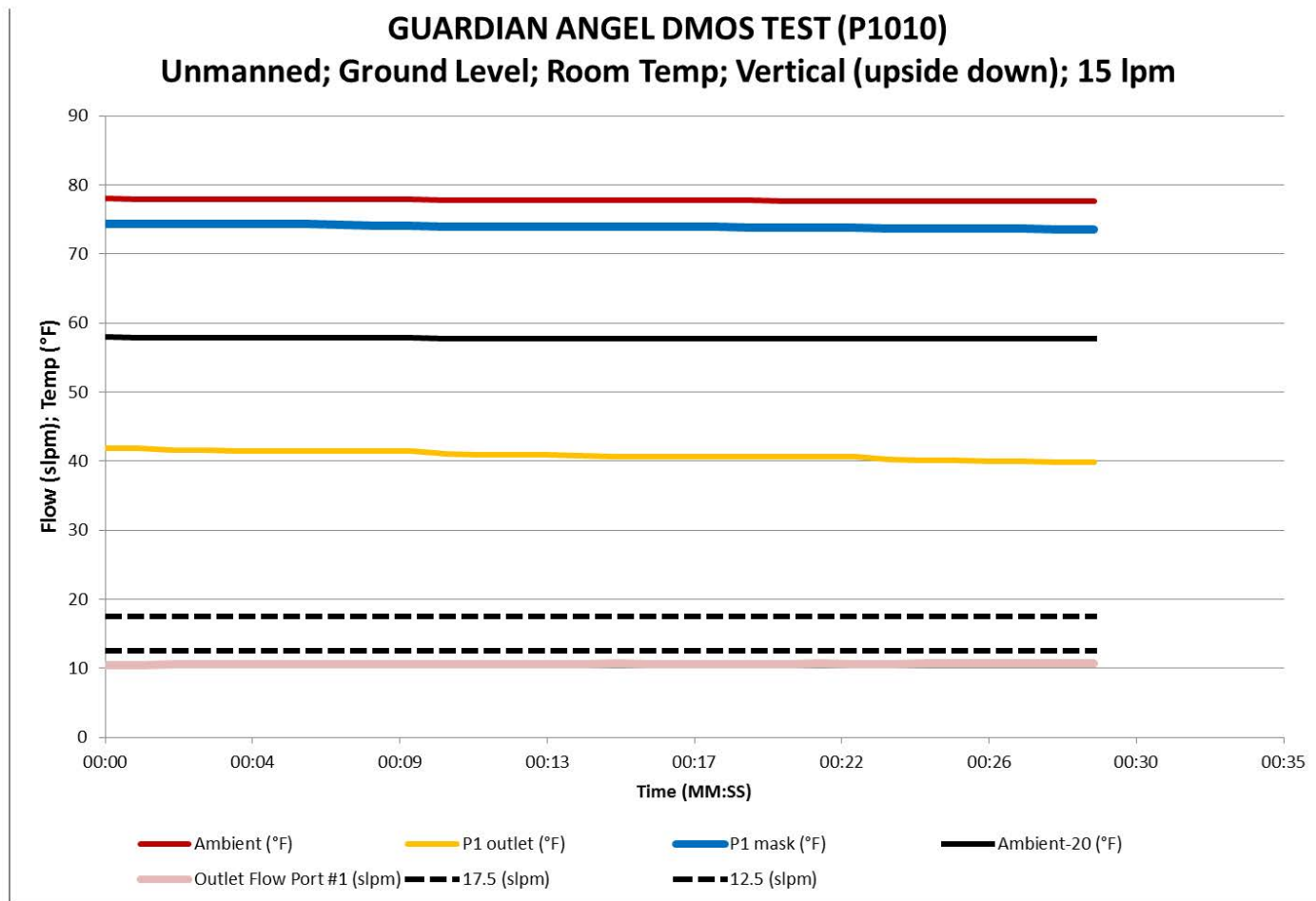


Figure D-28

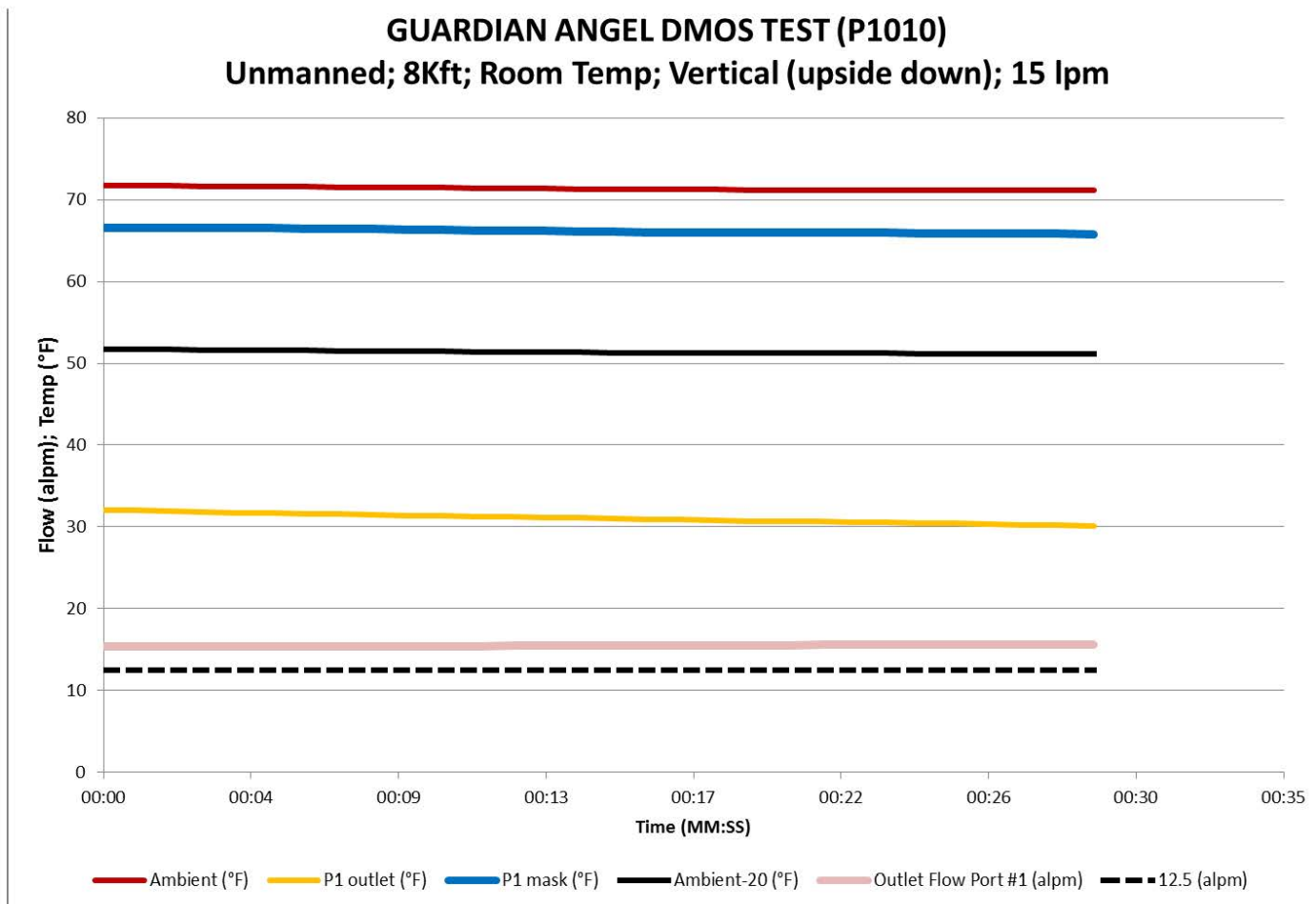


Figure D-29

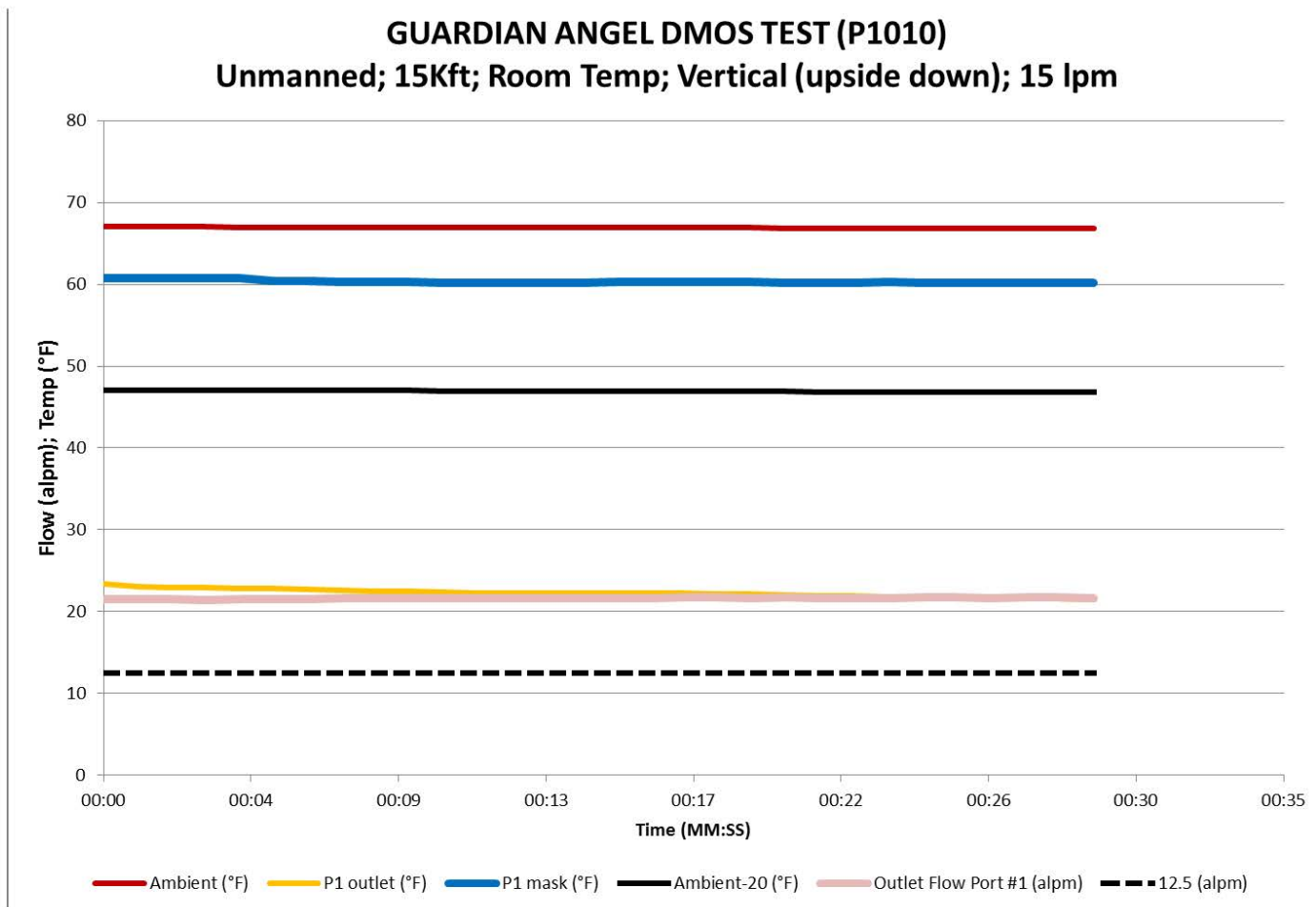


Figure D-30

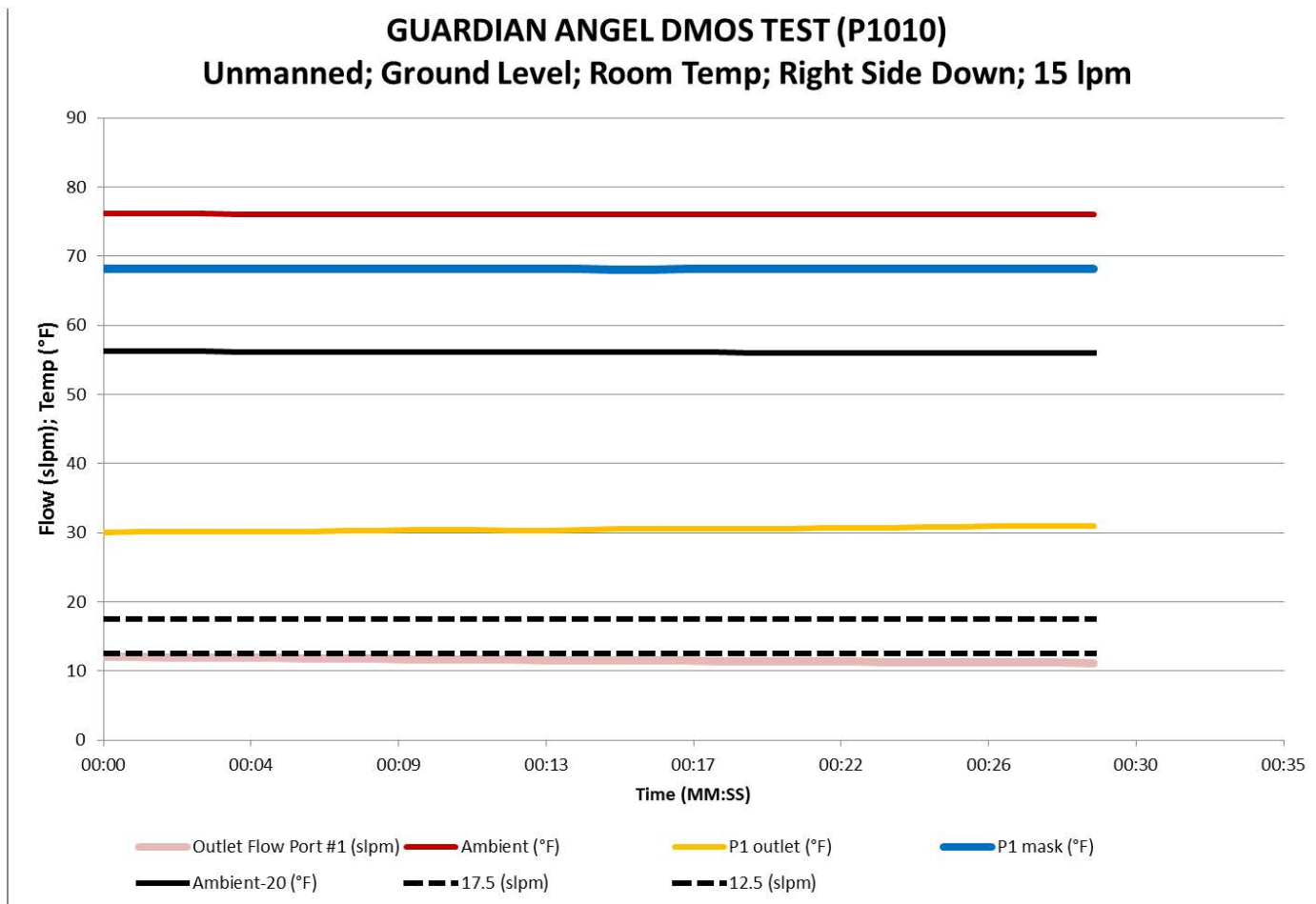


Figure D-31

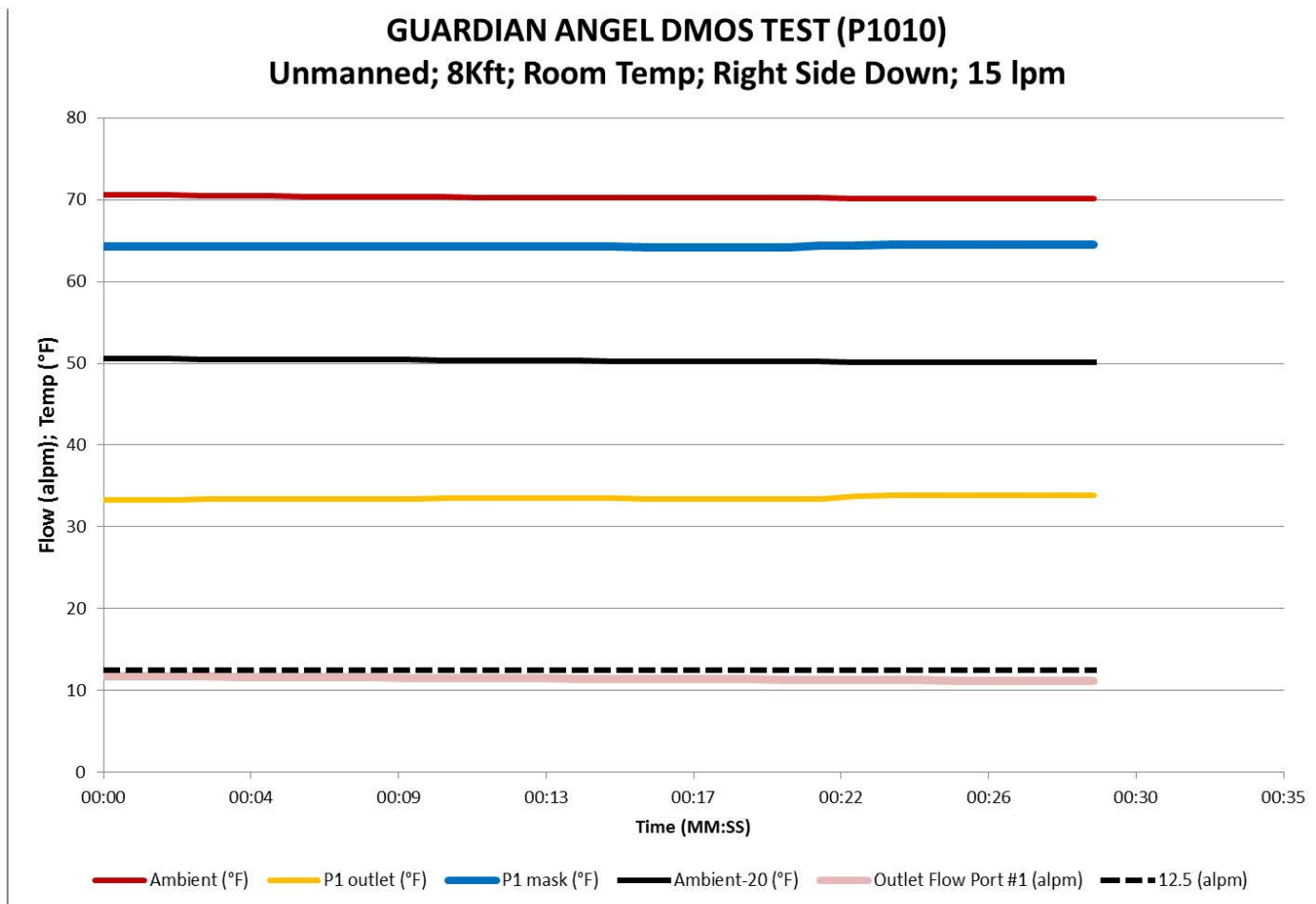


Figure D-32

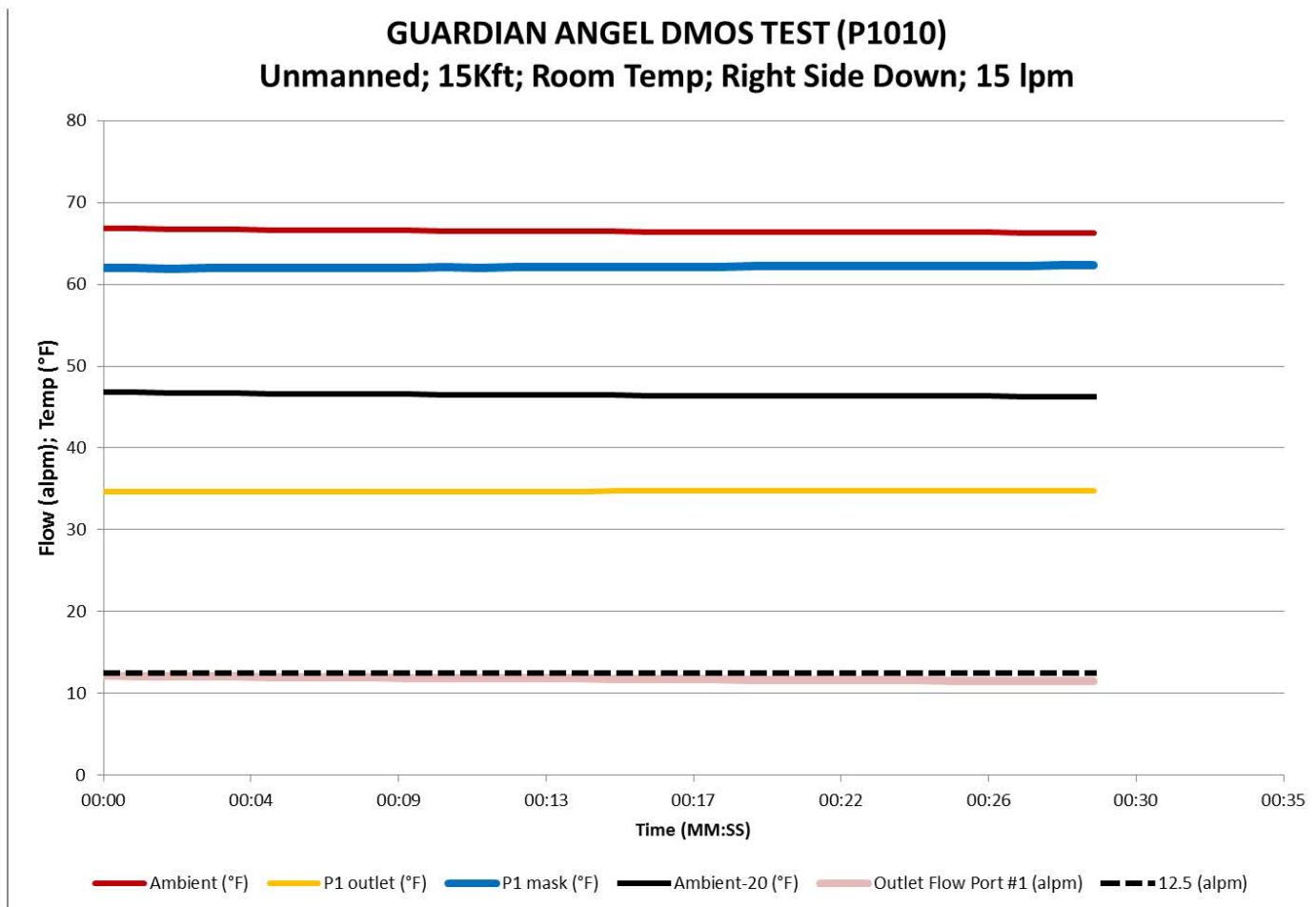


Figure D-33

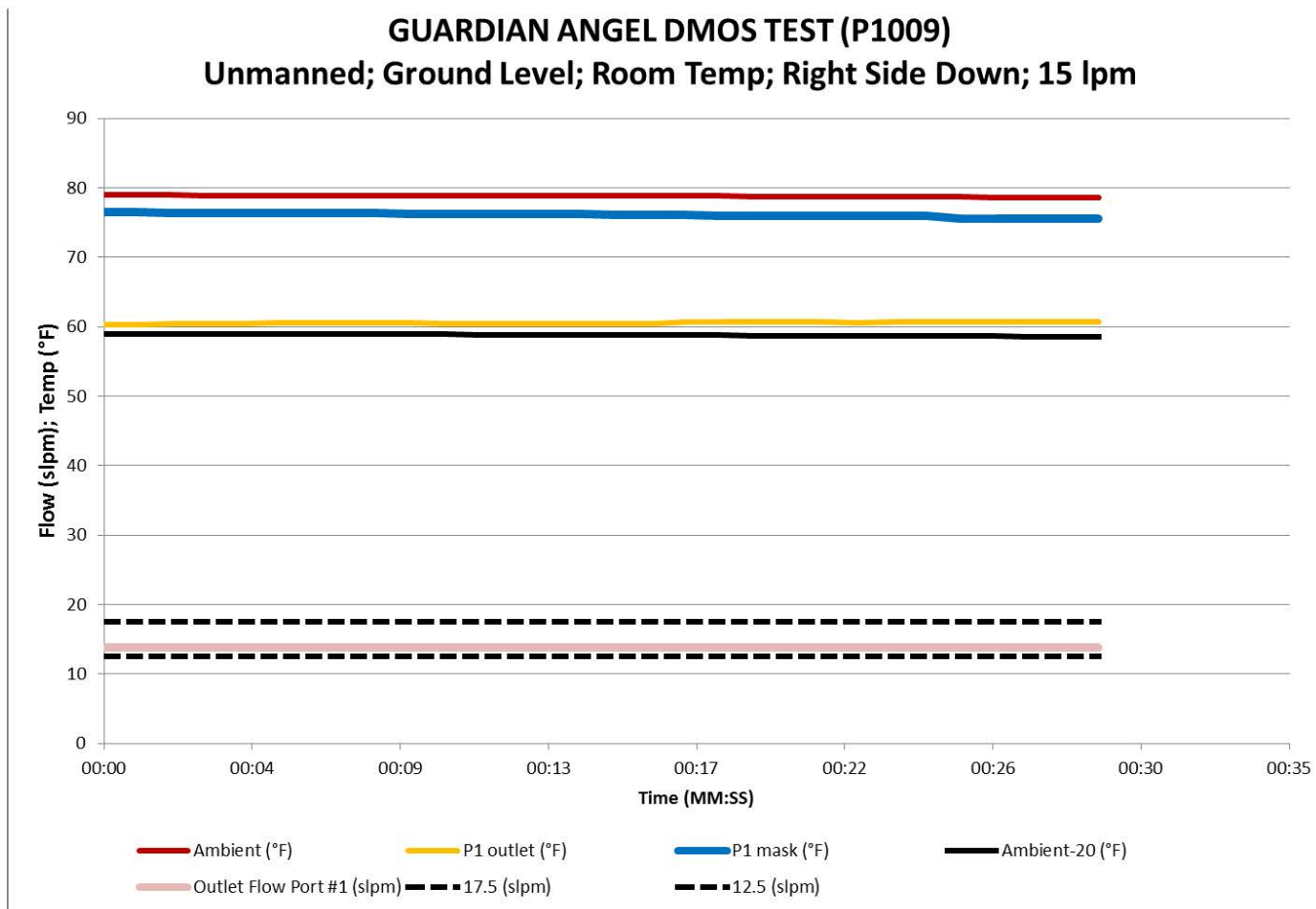


Figure D-34

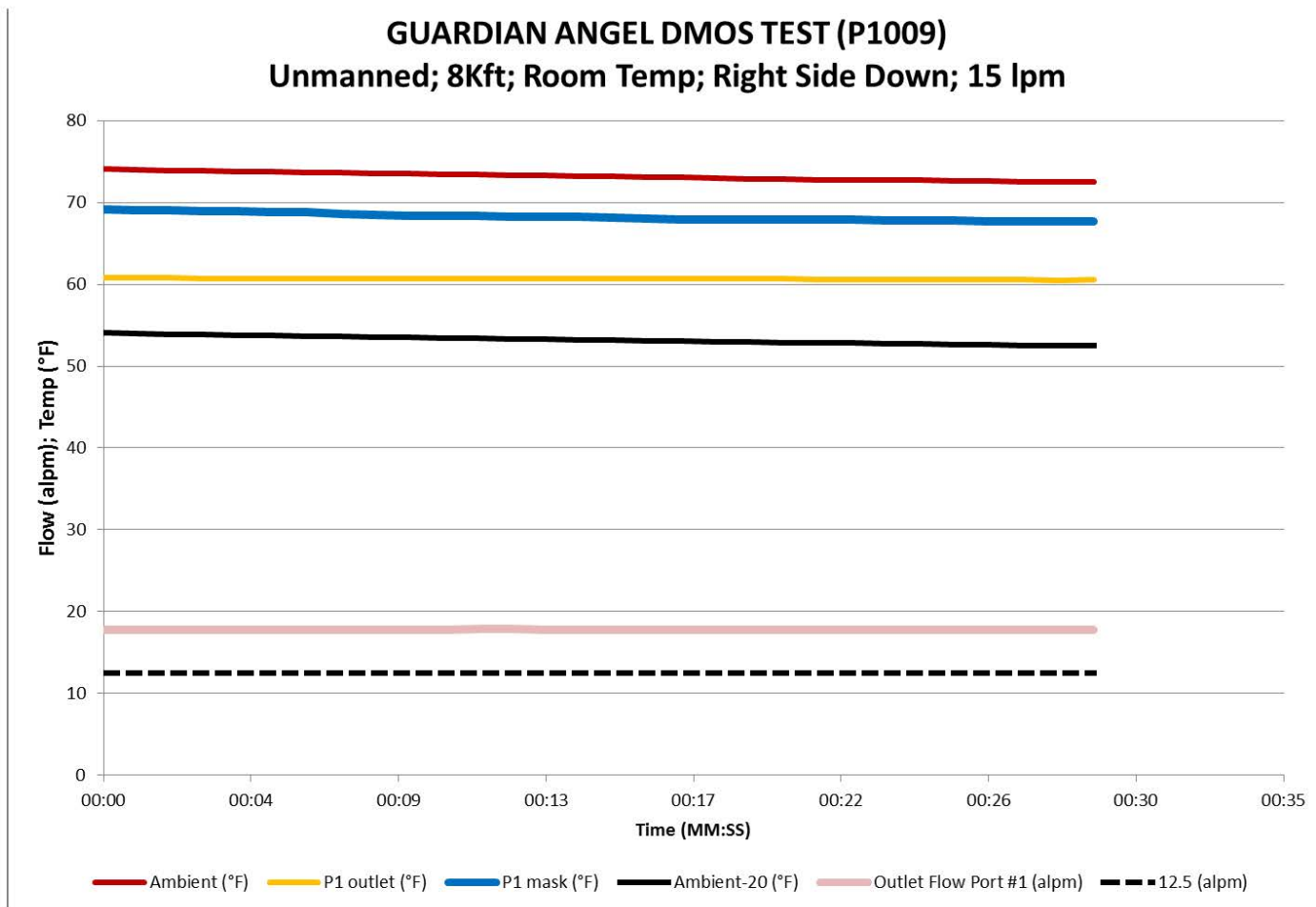


Figure D-35

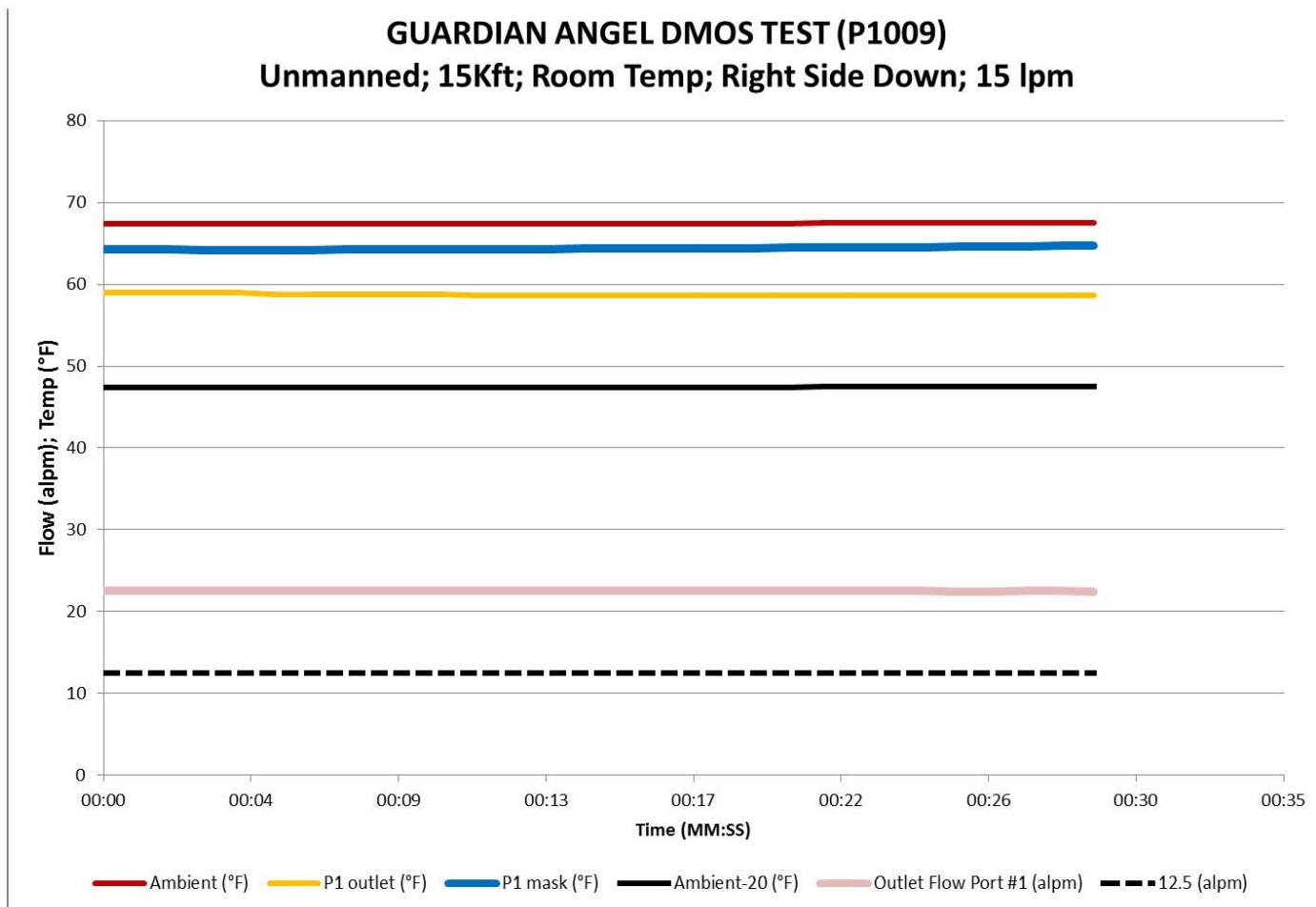


Figure D-36

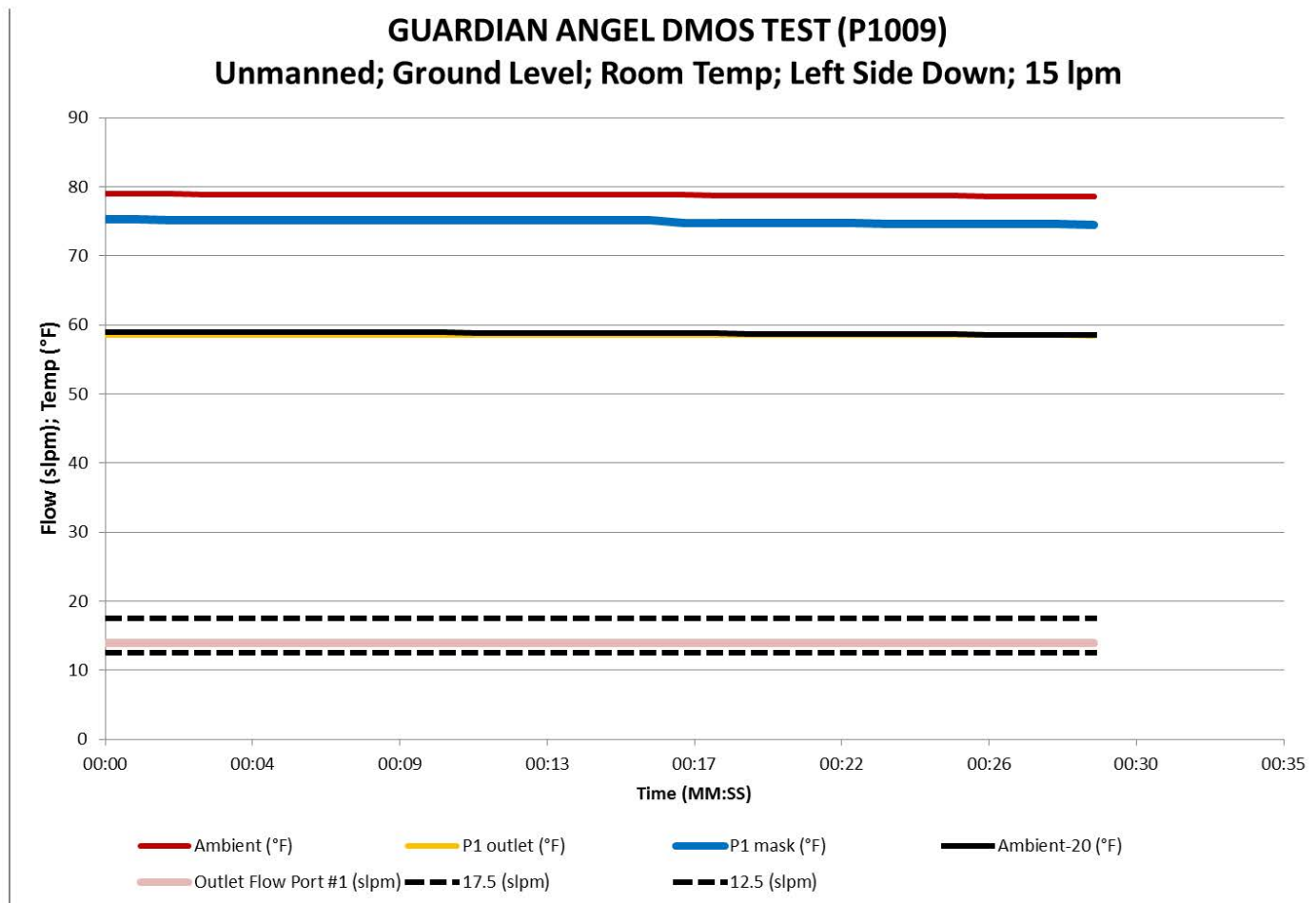


Figure D-37

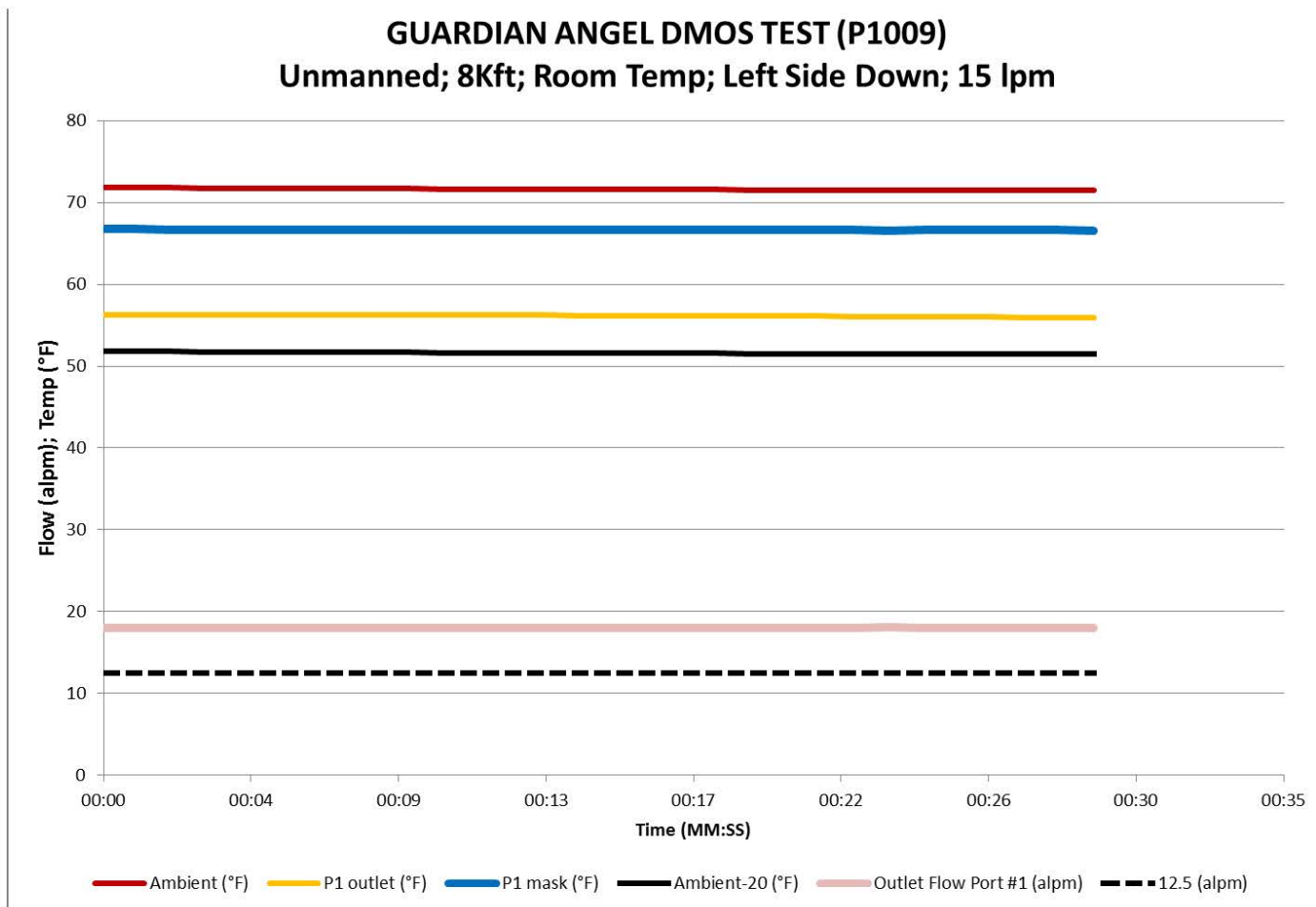


Figure D-38

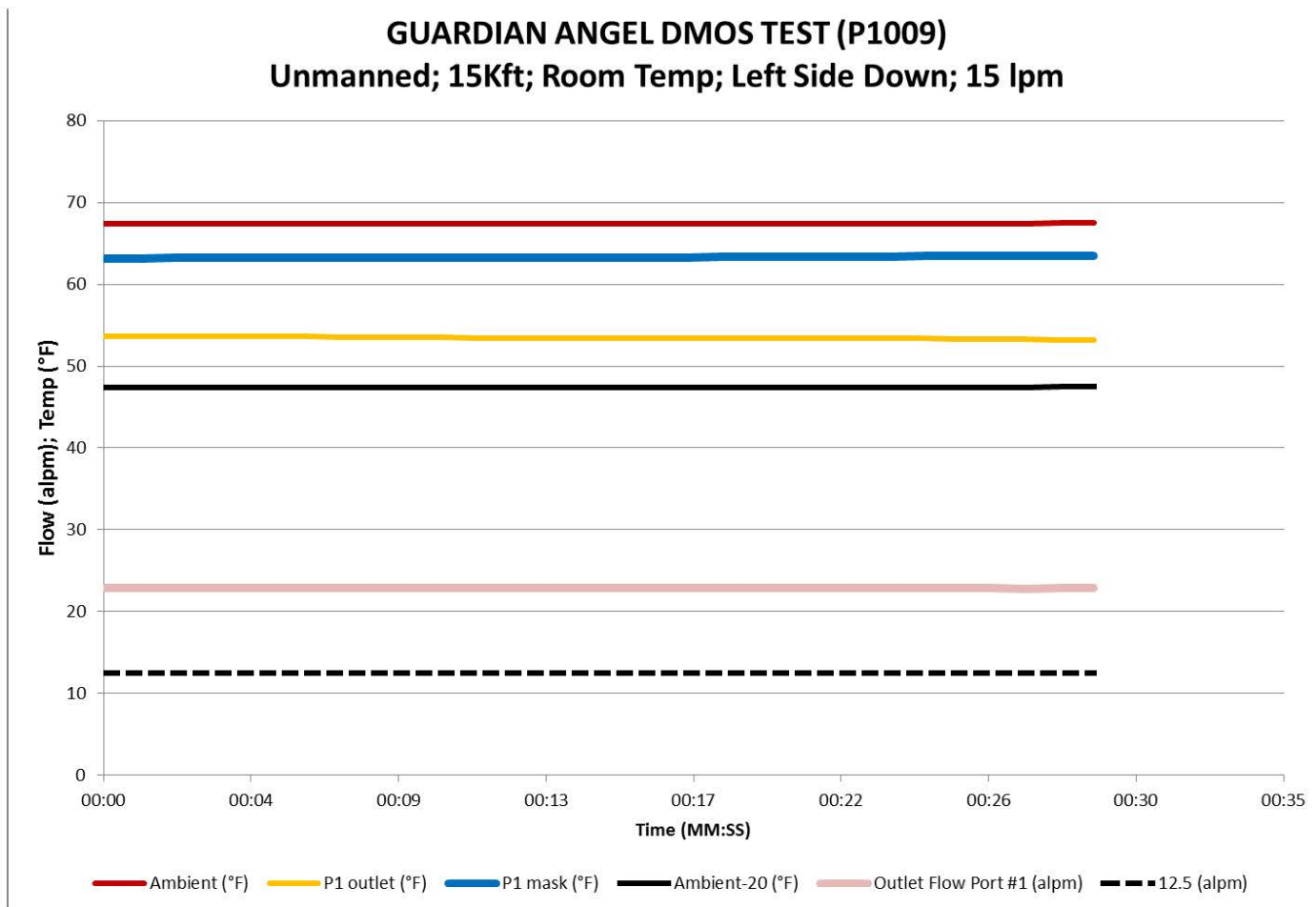


Figure D-39

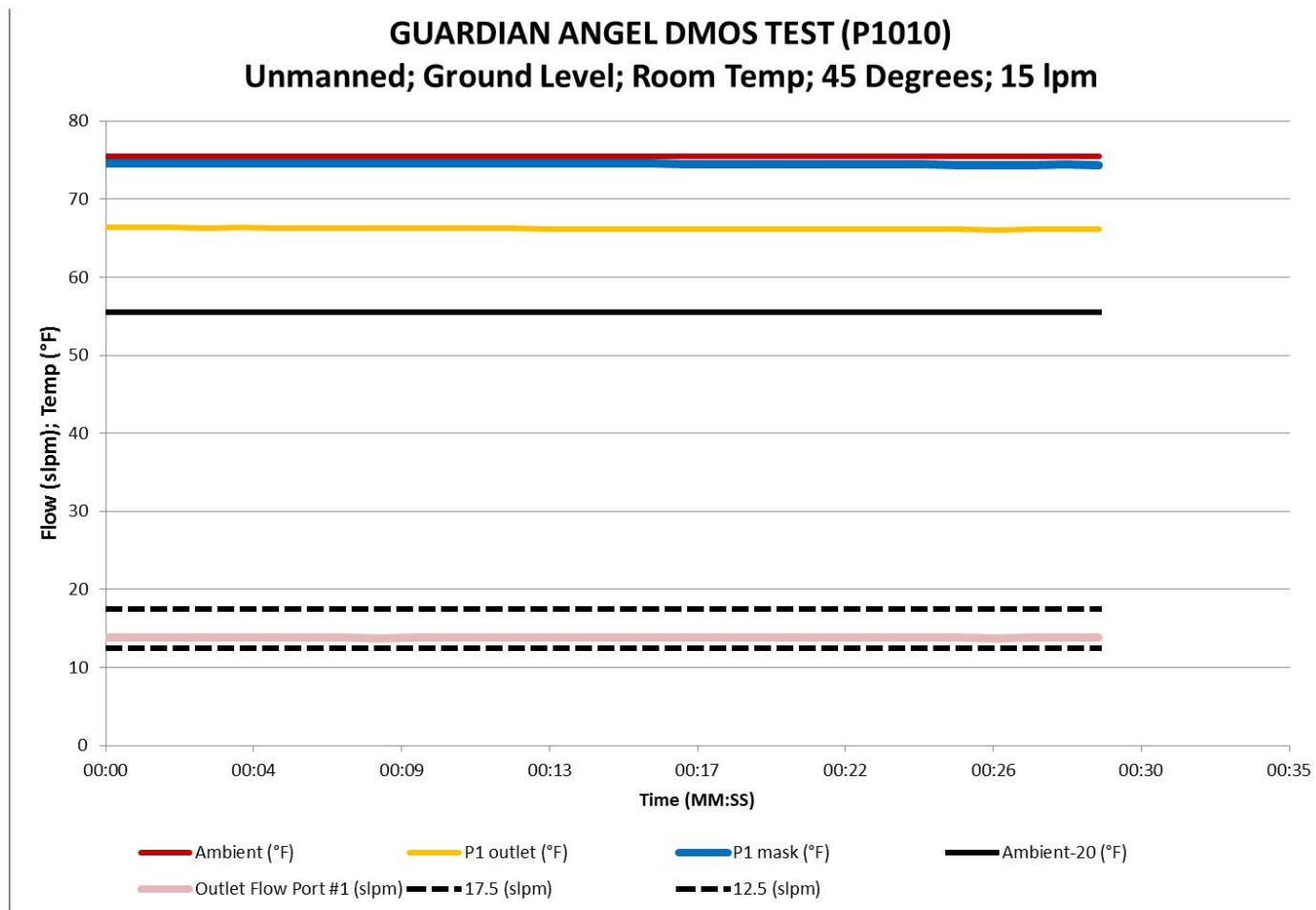


Figure D-40

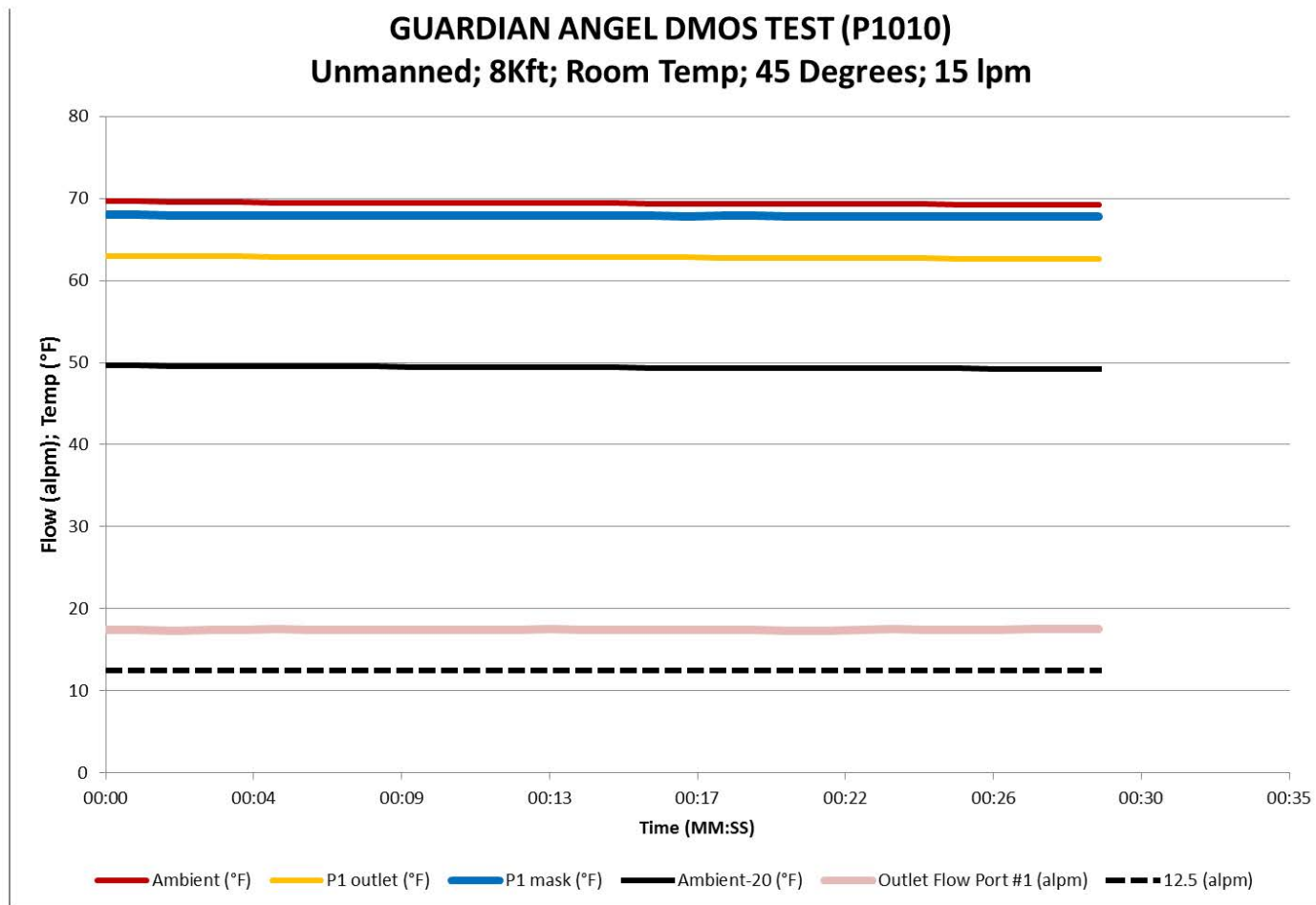


Figure D-41

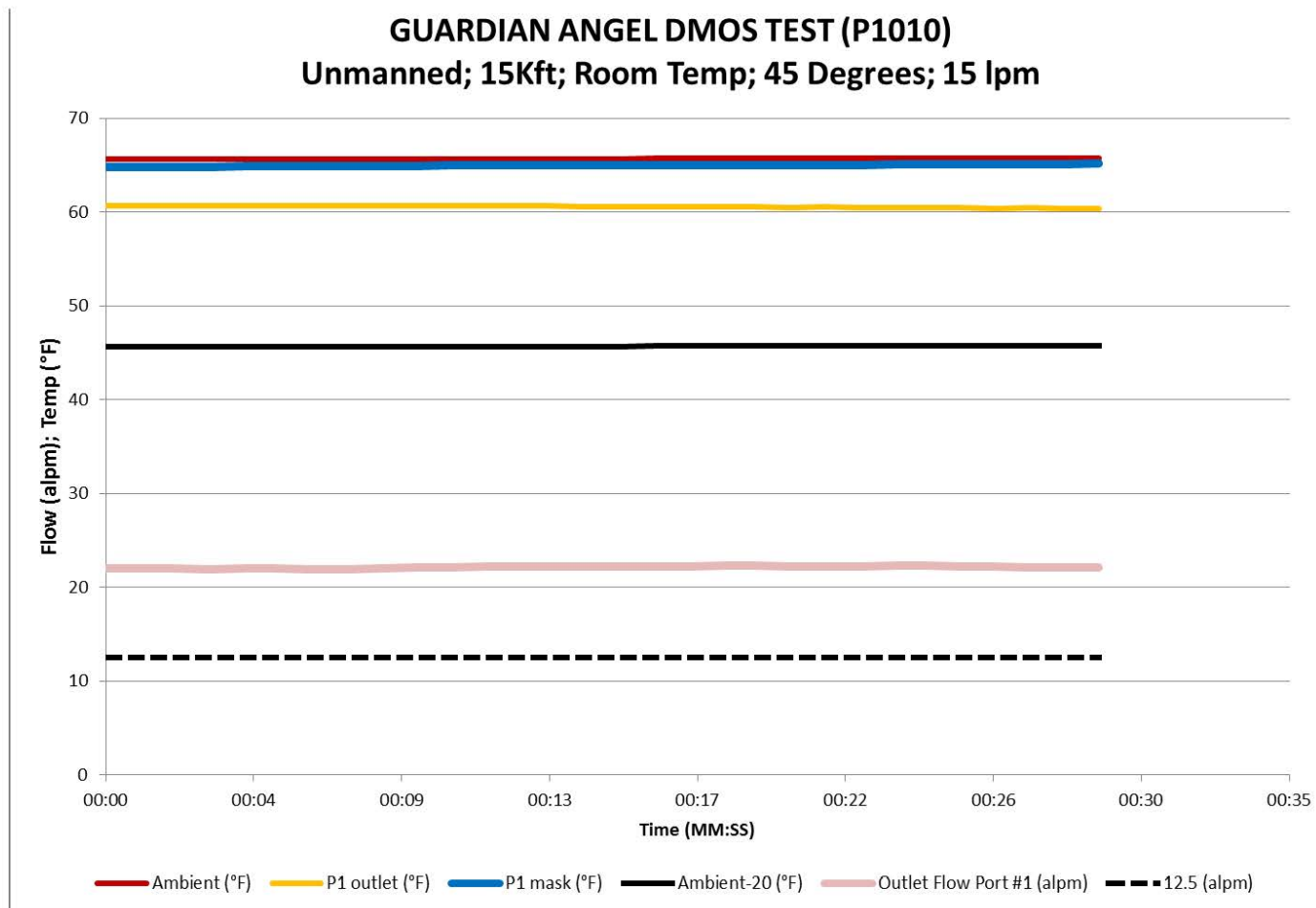


Figure D-42

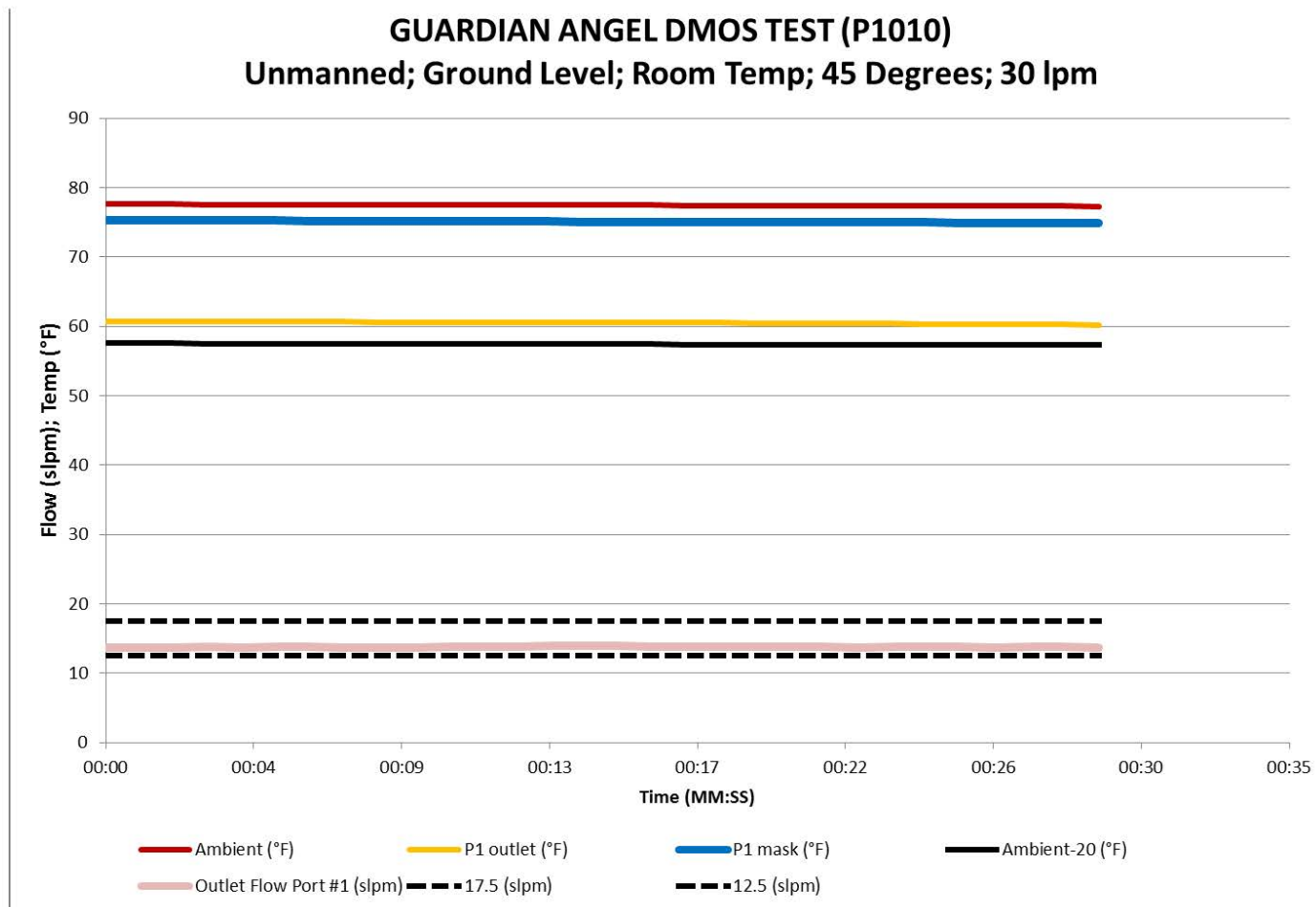


Figure D-43

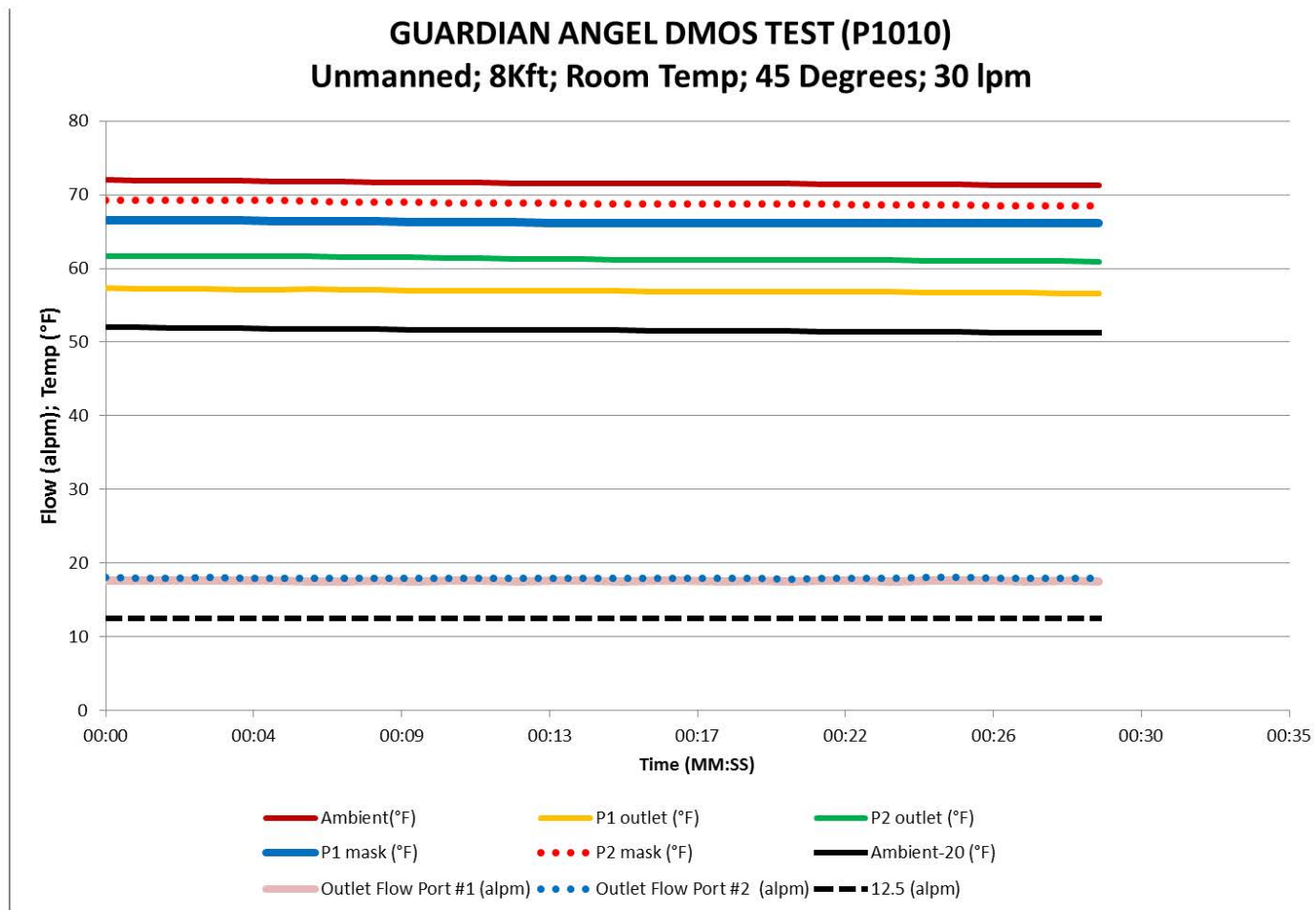


Figure D-44

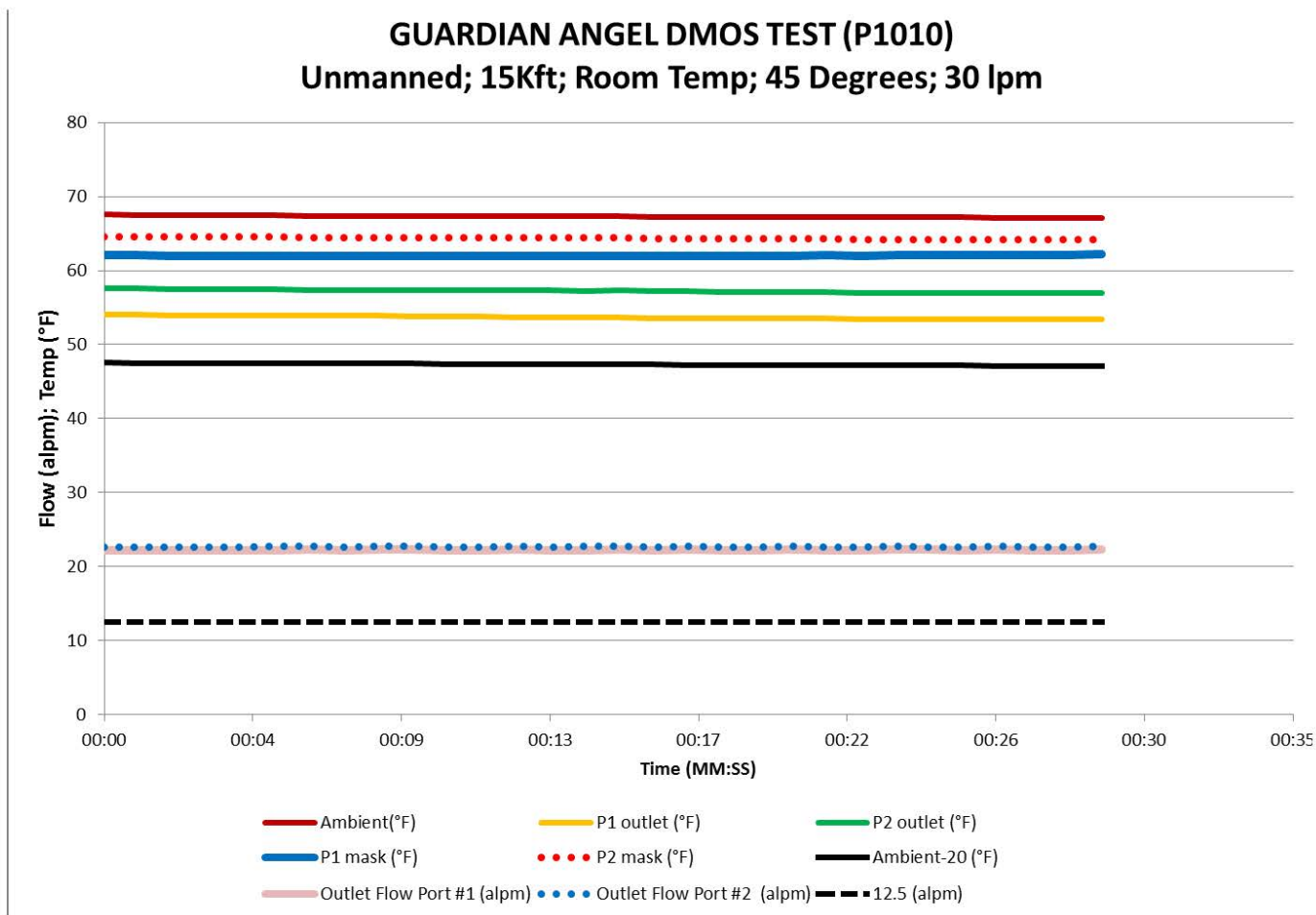


Figure D-45

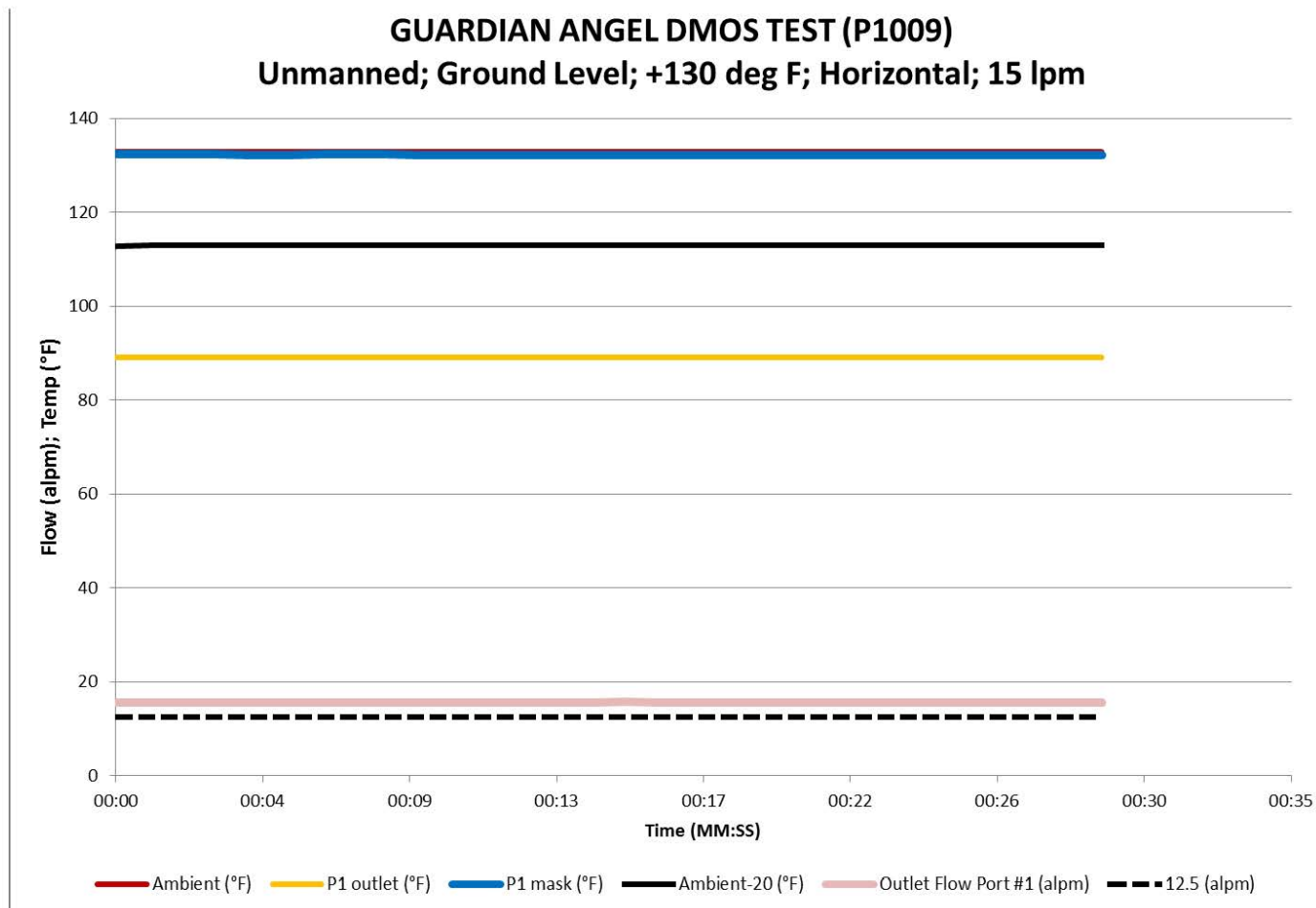


Figure D-46

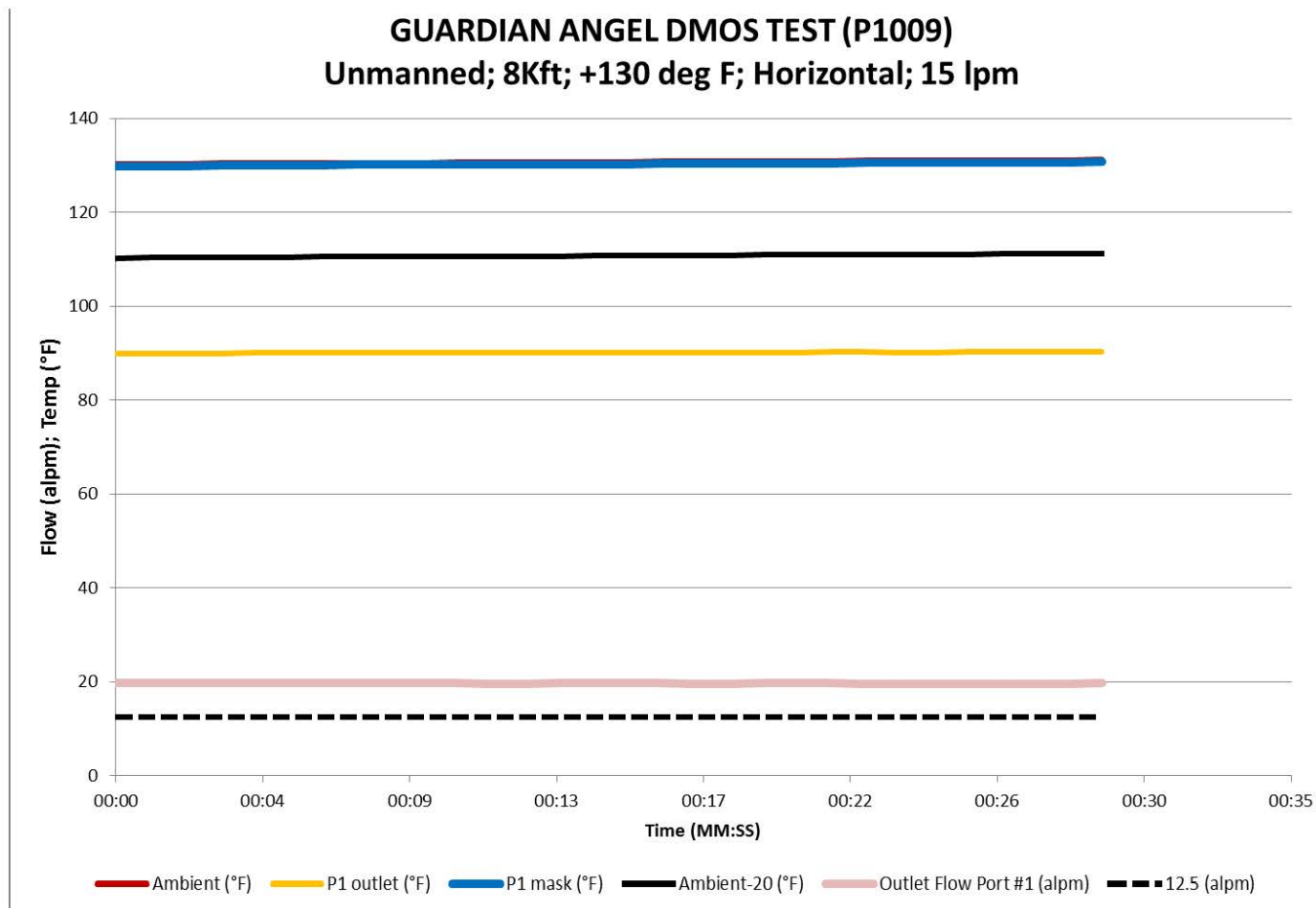


Figure D-47

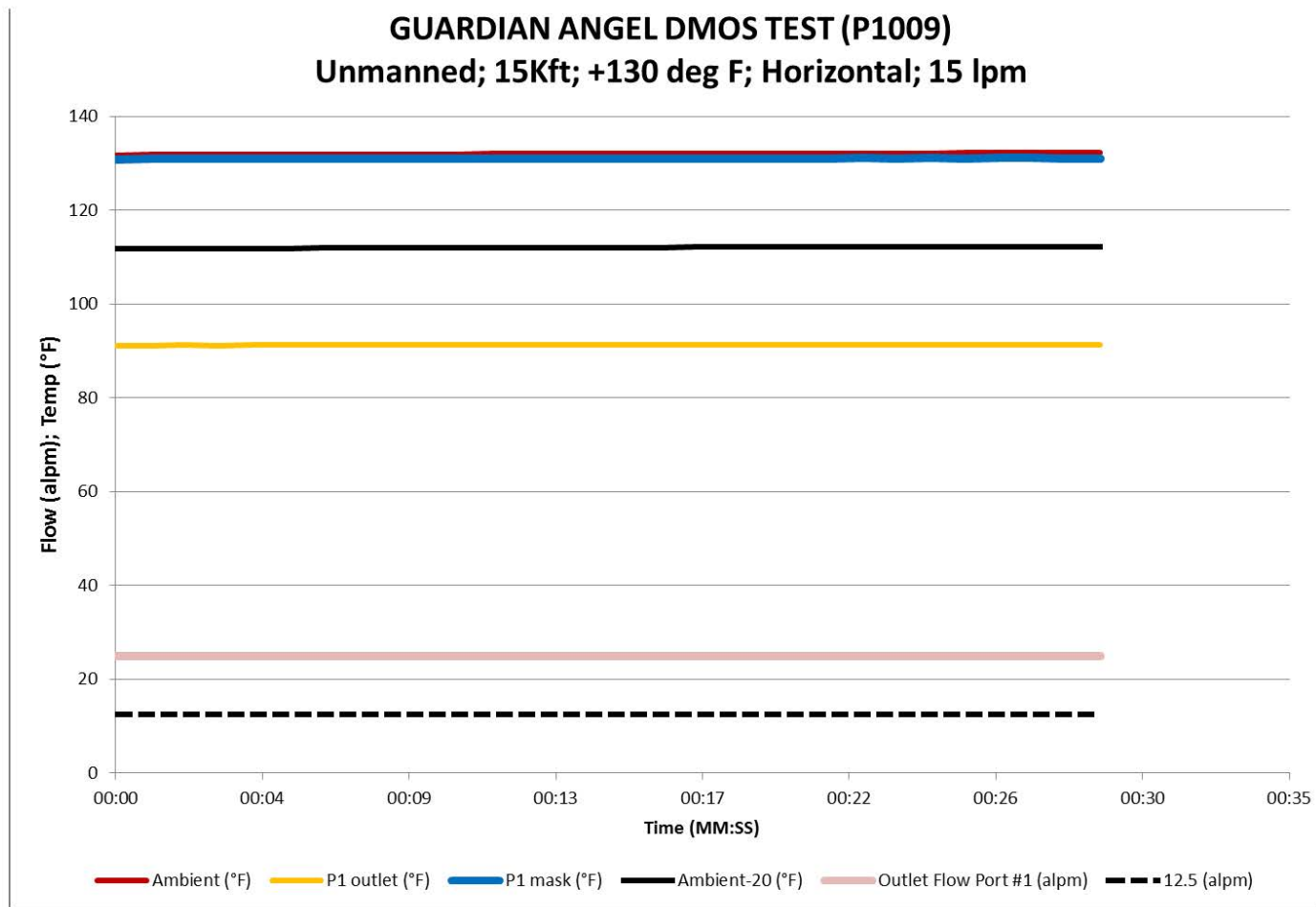


Figure D-48

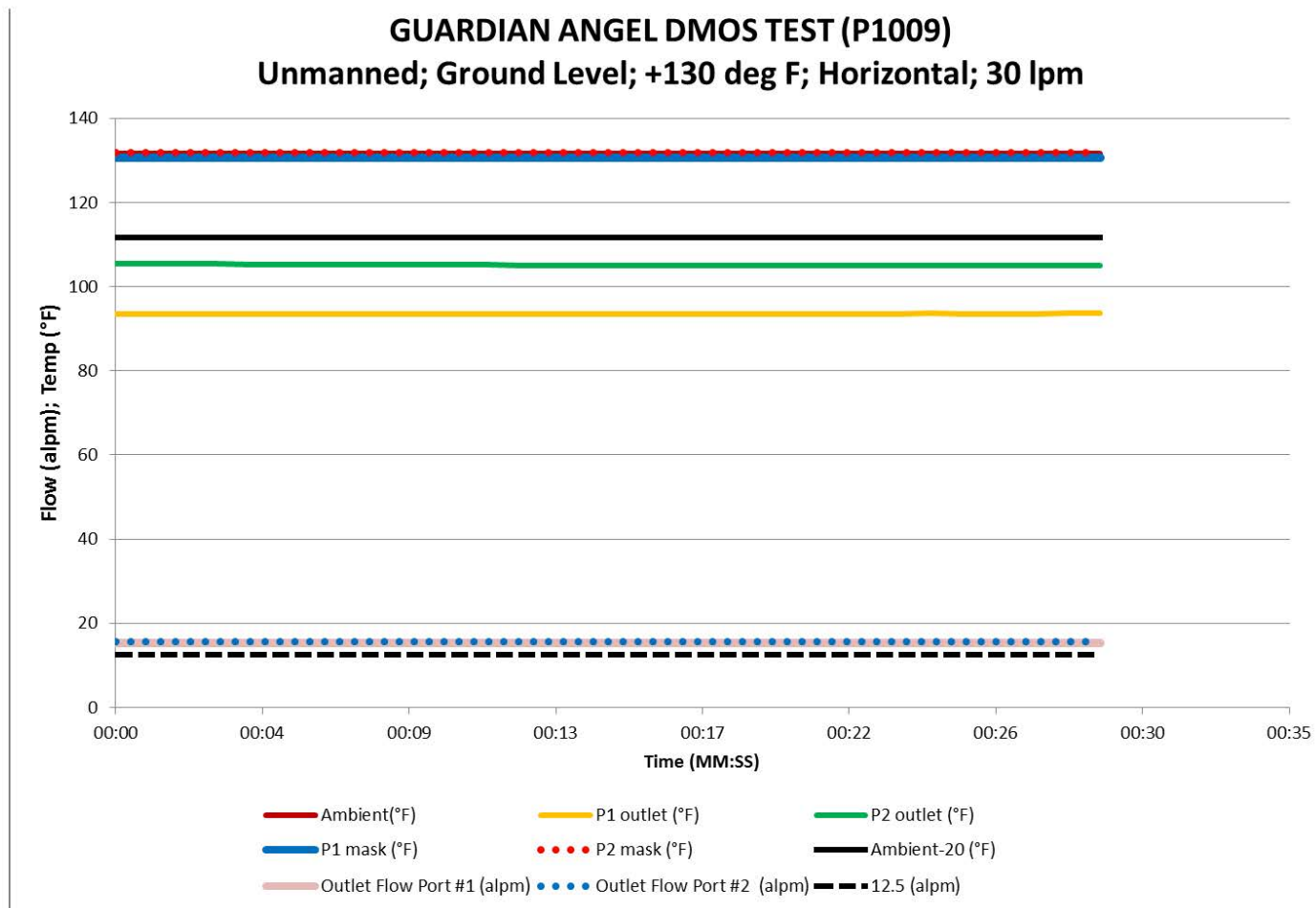


Figure D-49

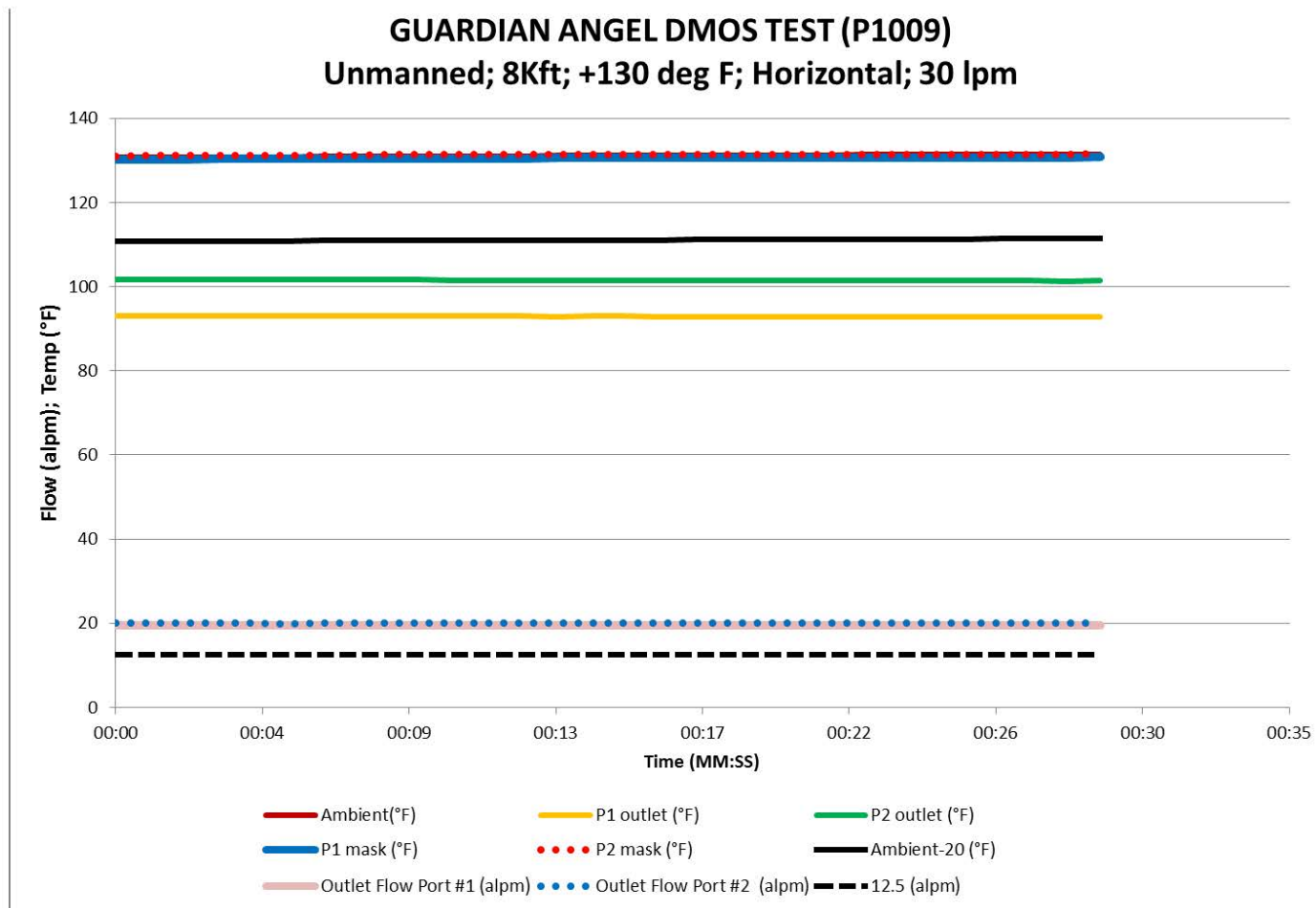


Figure D-50

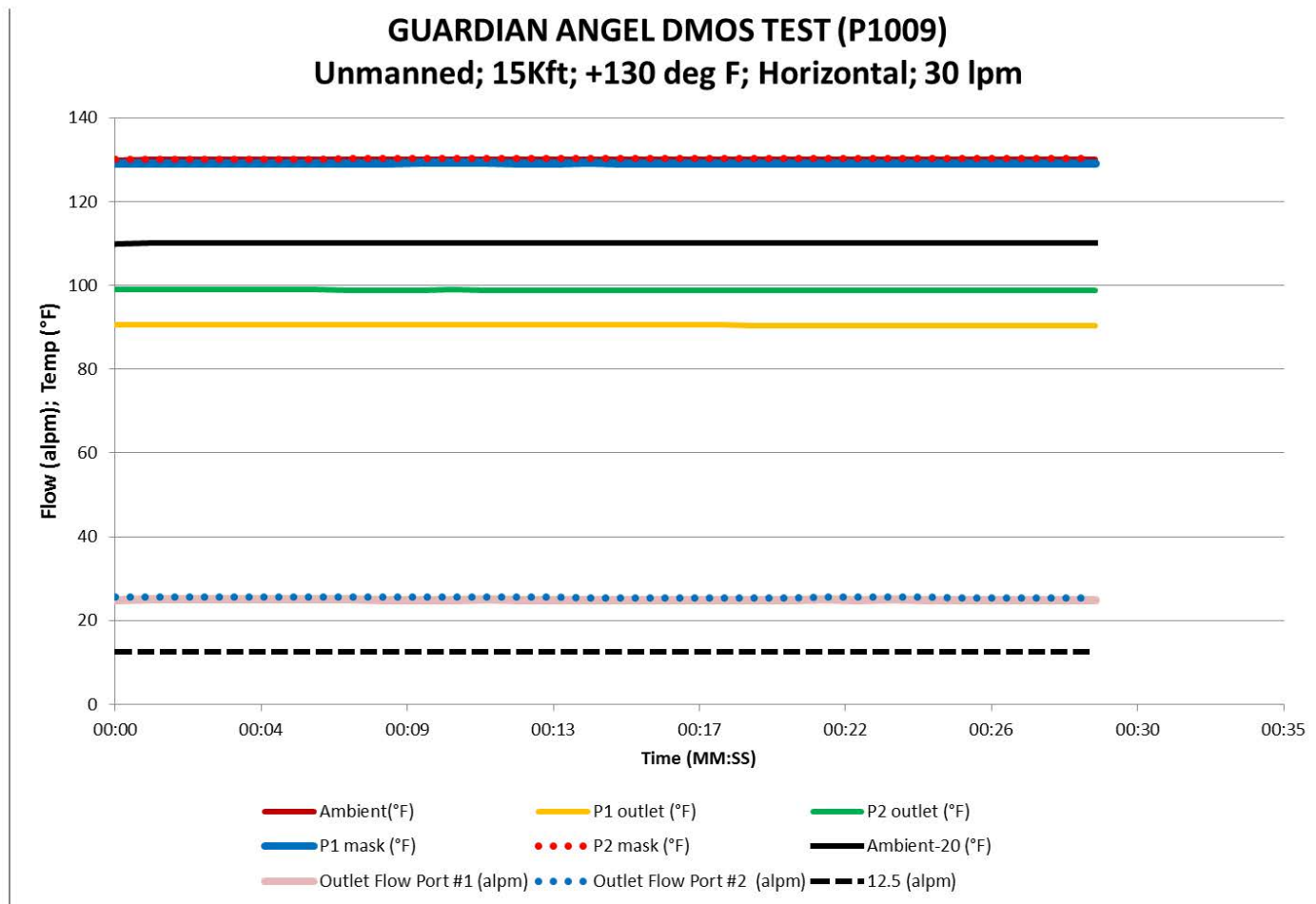


Figure D-51

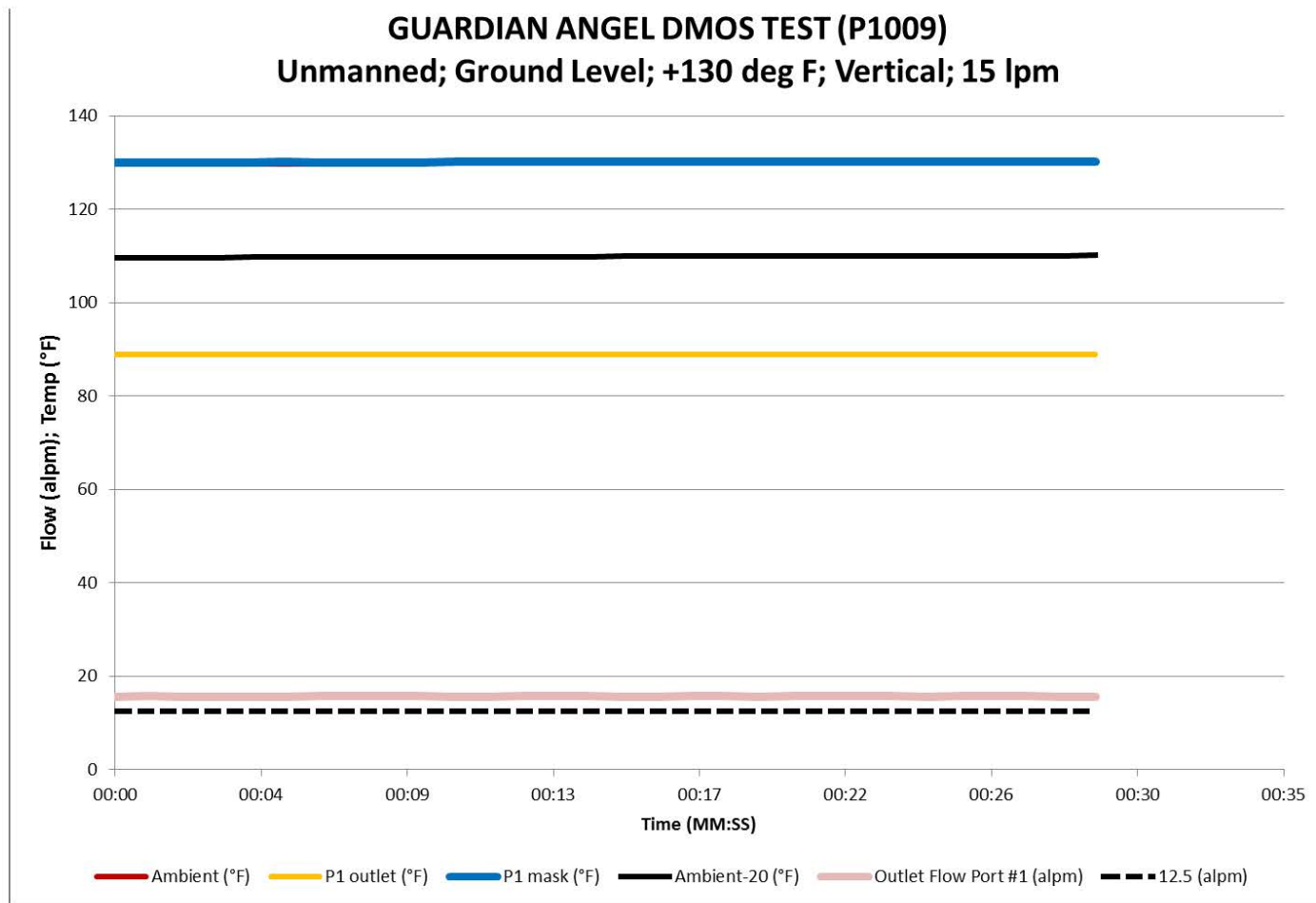


Figure D-52

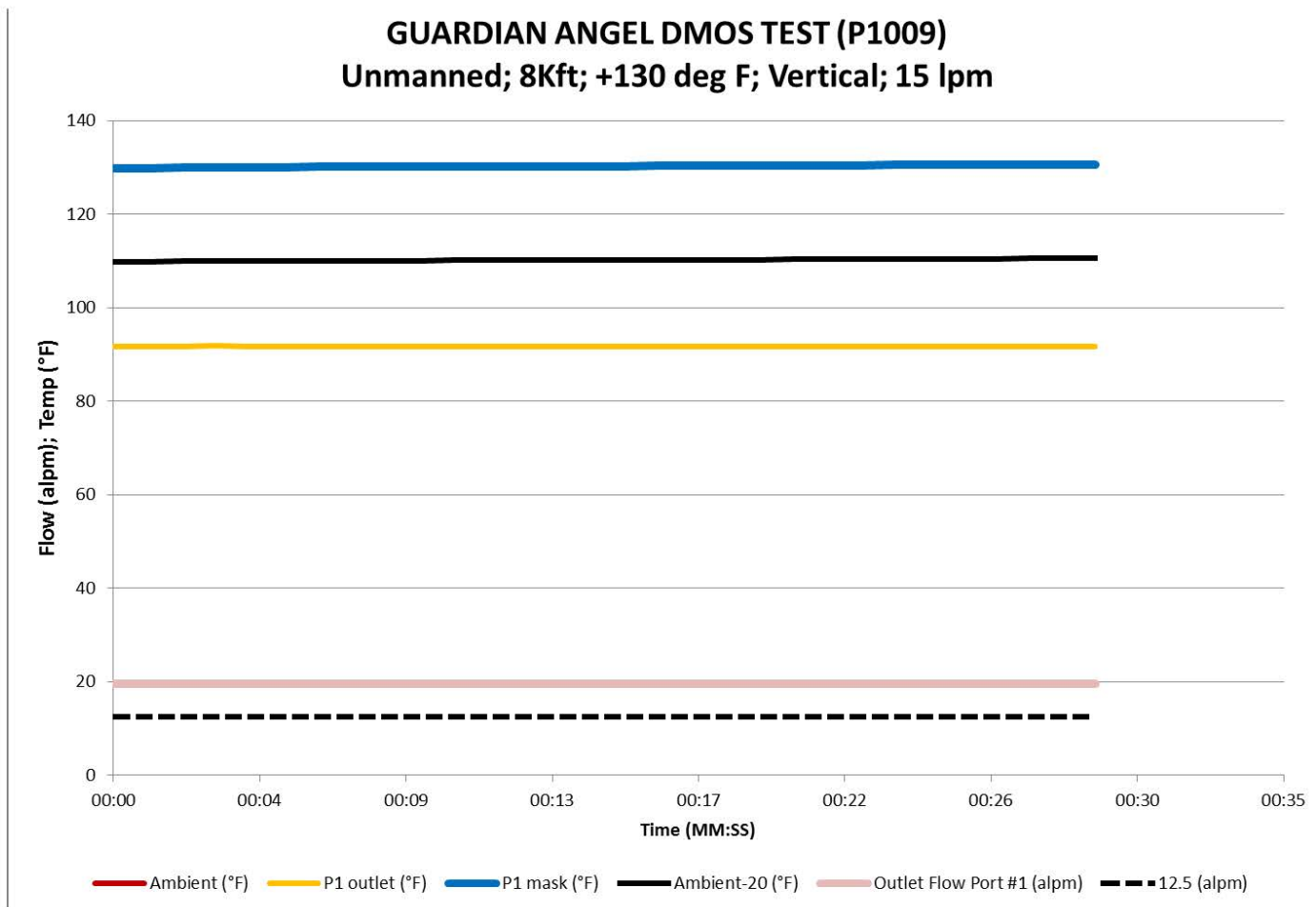


Figure D-53

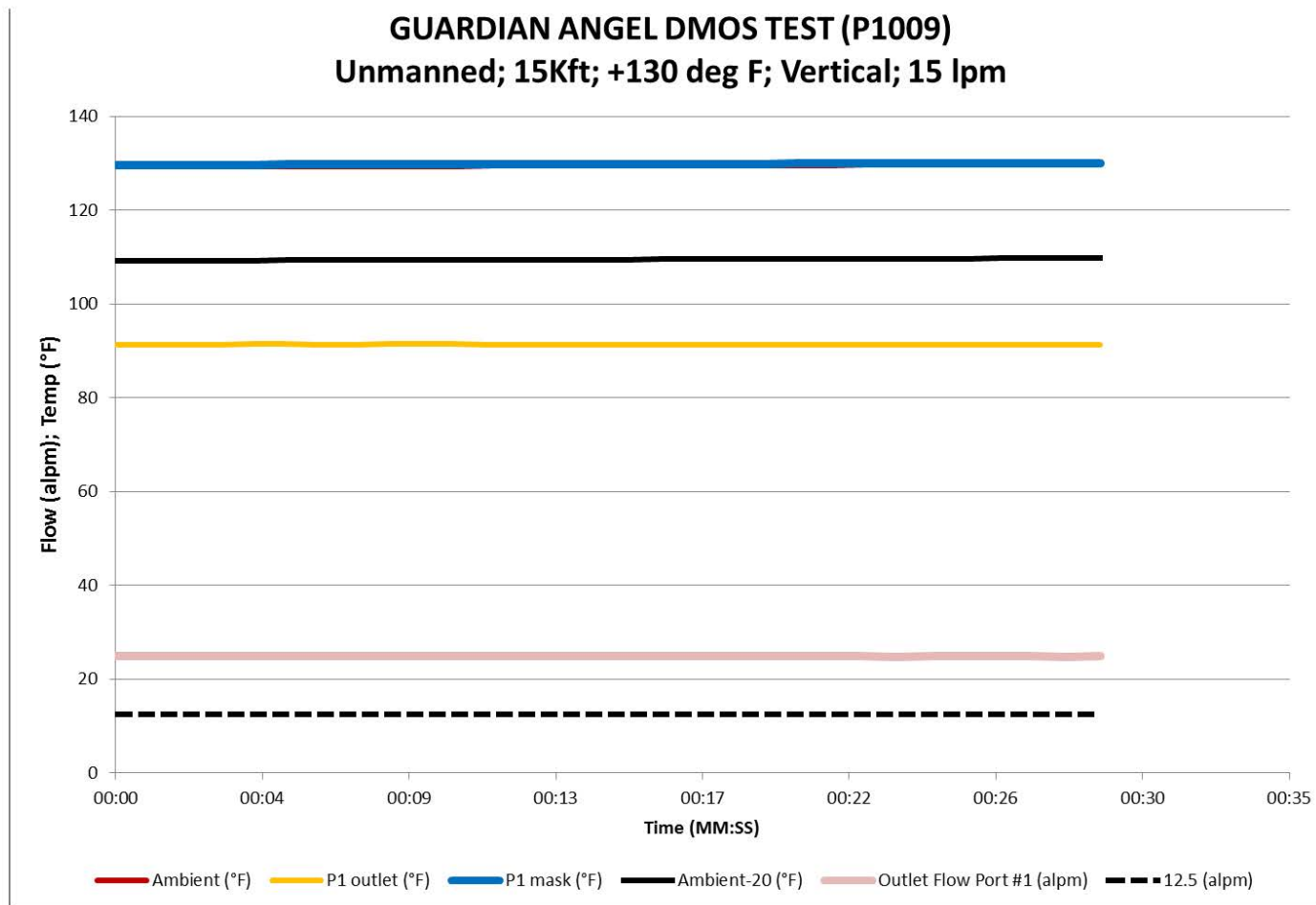


Figure D-54

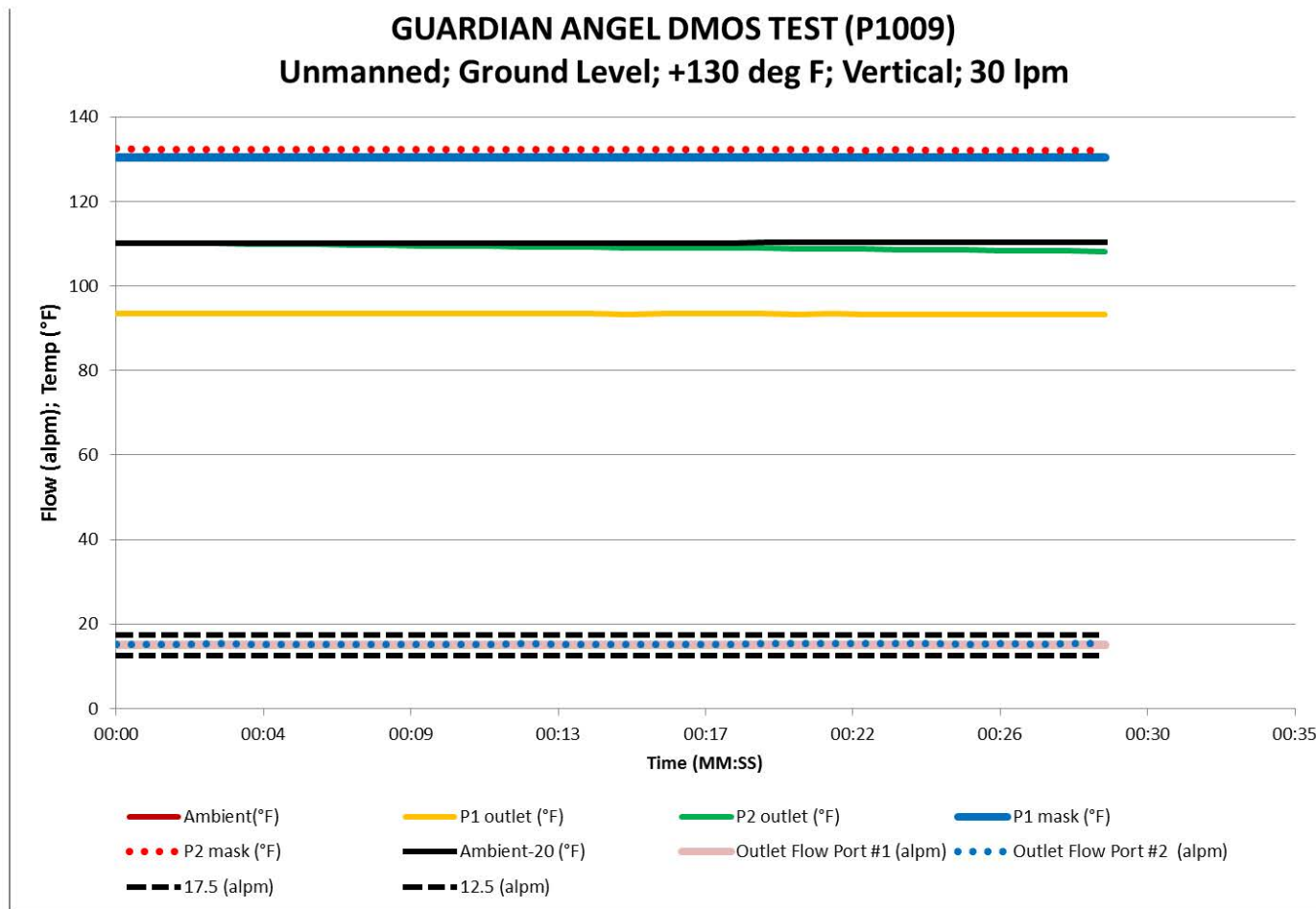


Figure D-55

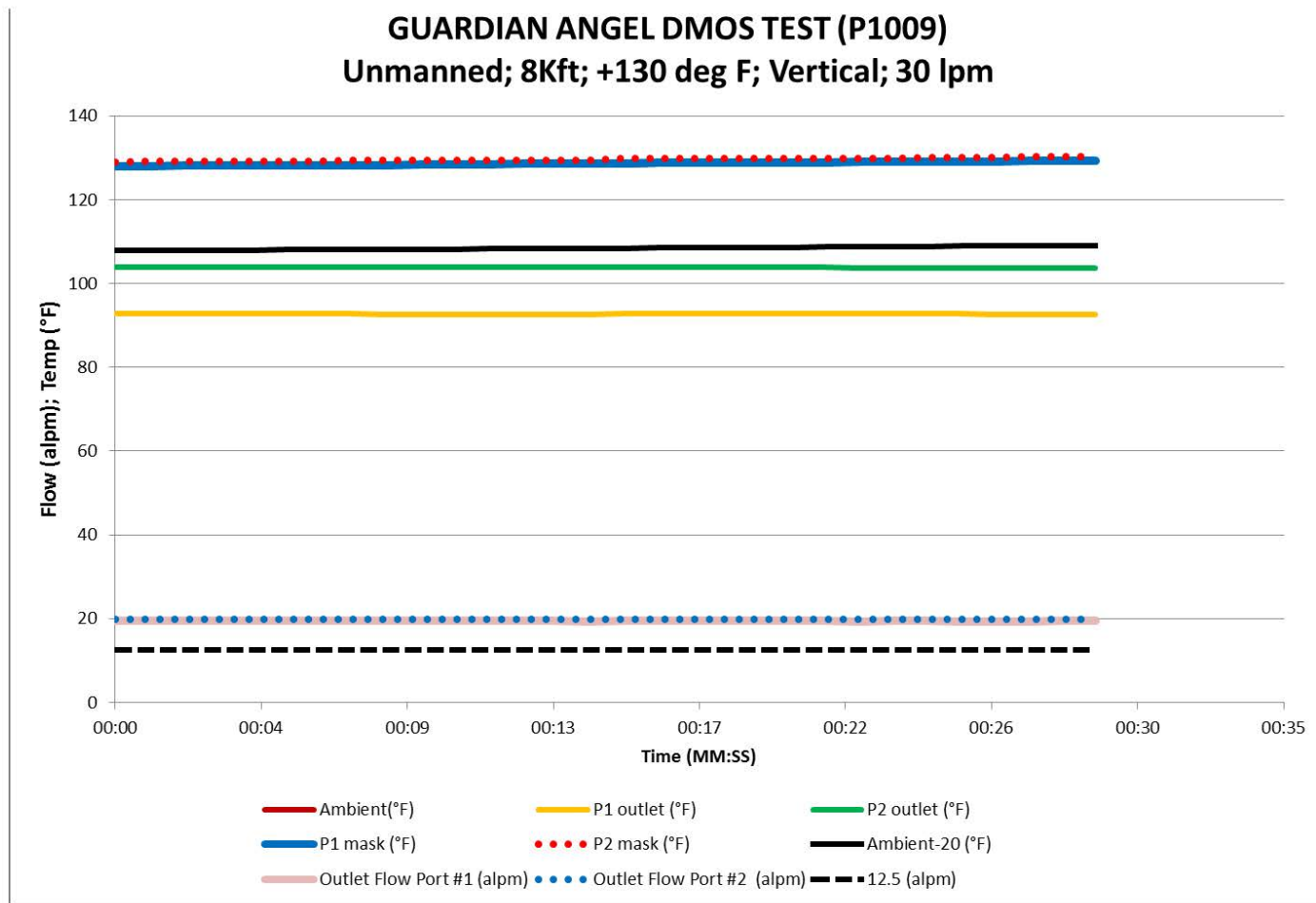


Figure D-56

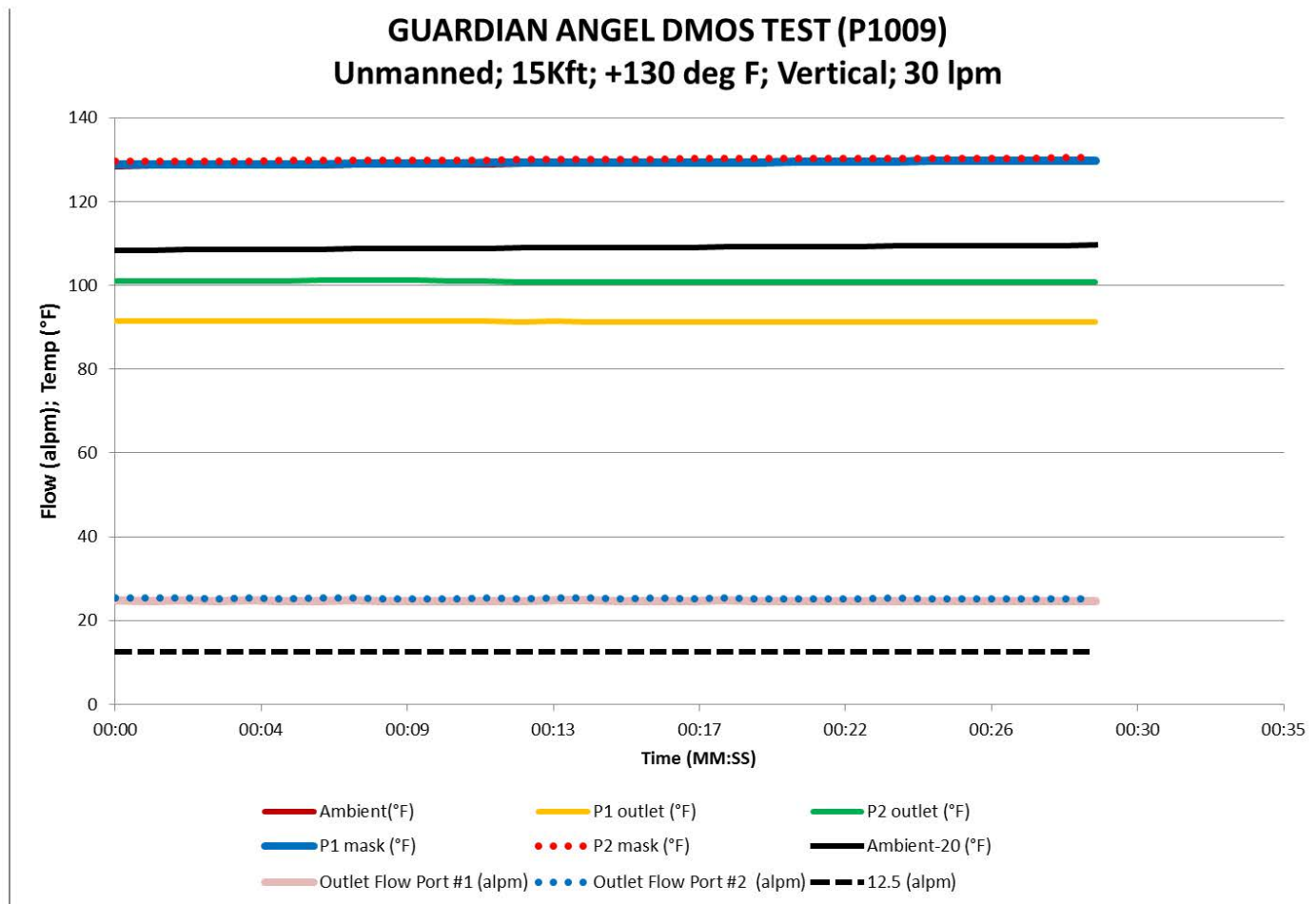


Figure D-57

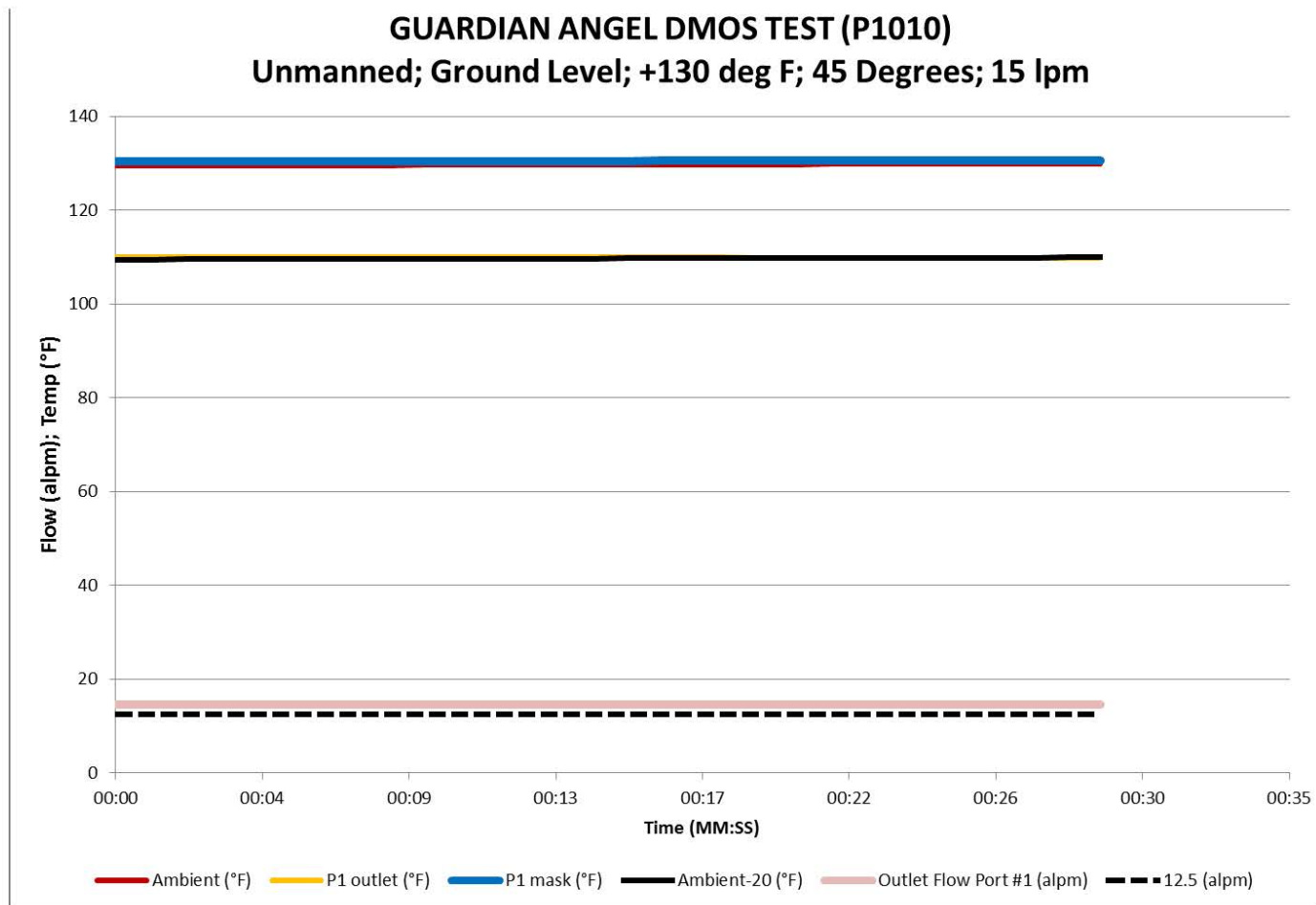


Figure D-58

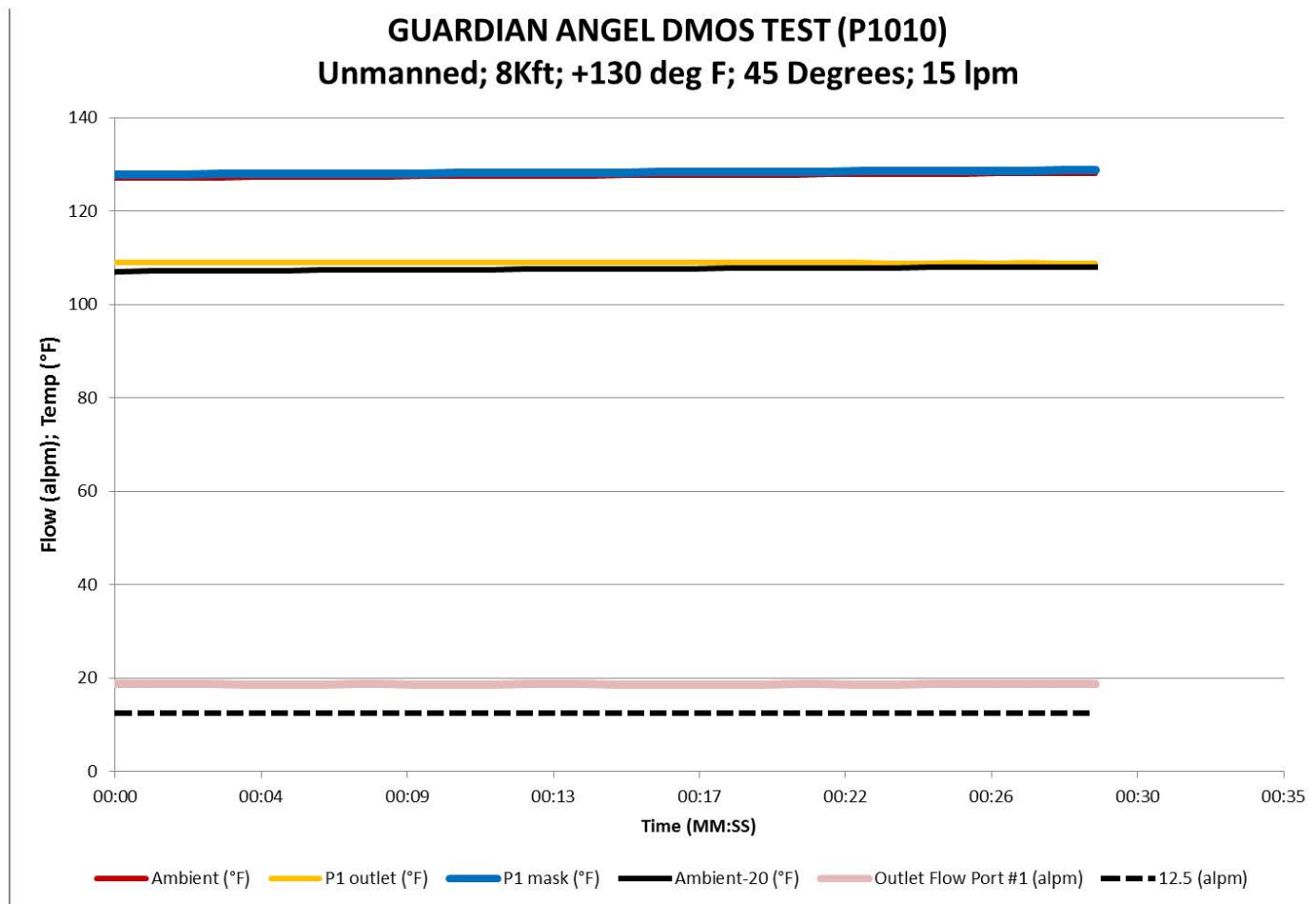


Figure D-59

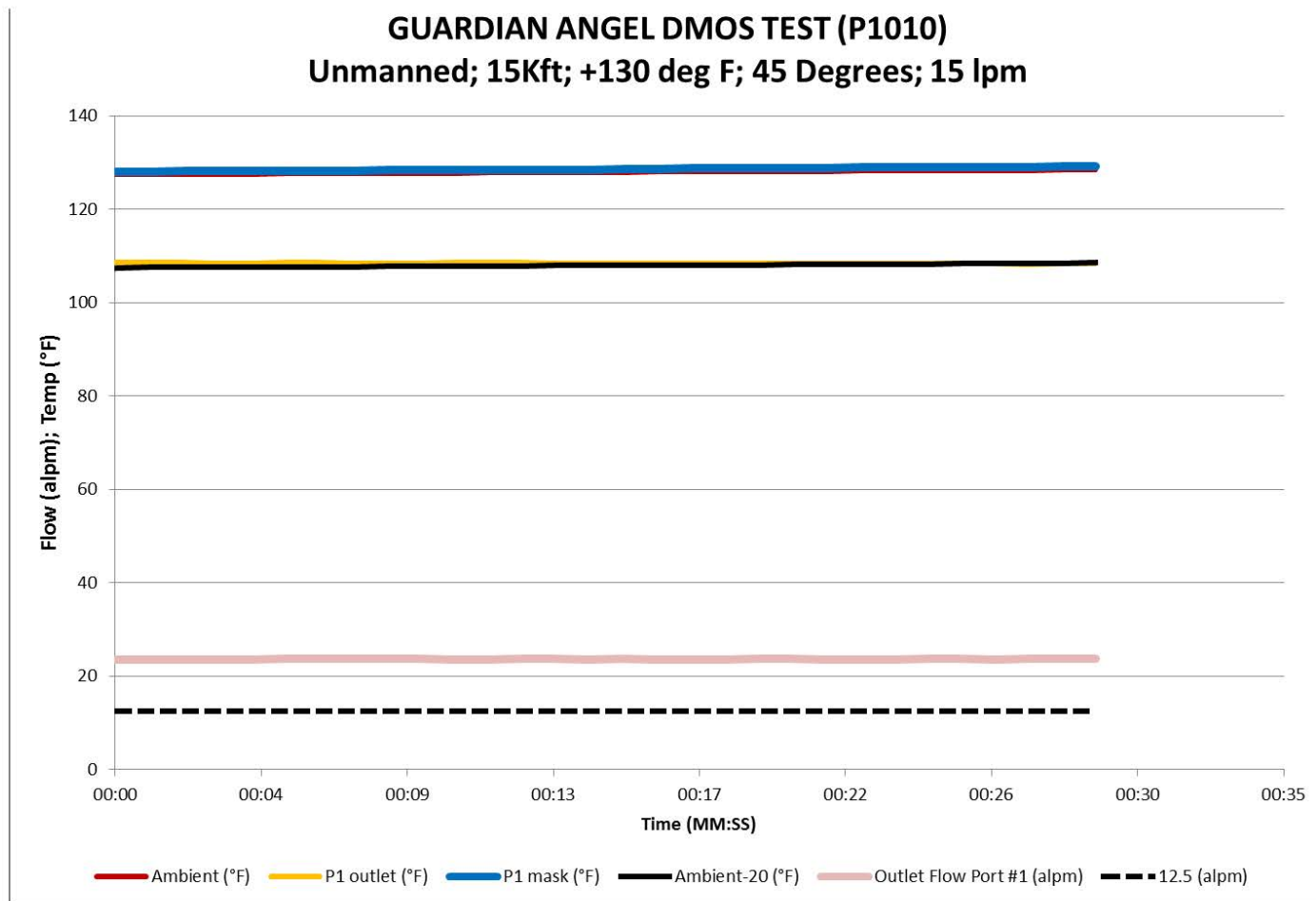


Figure D-60

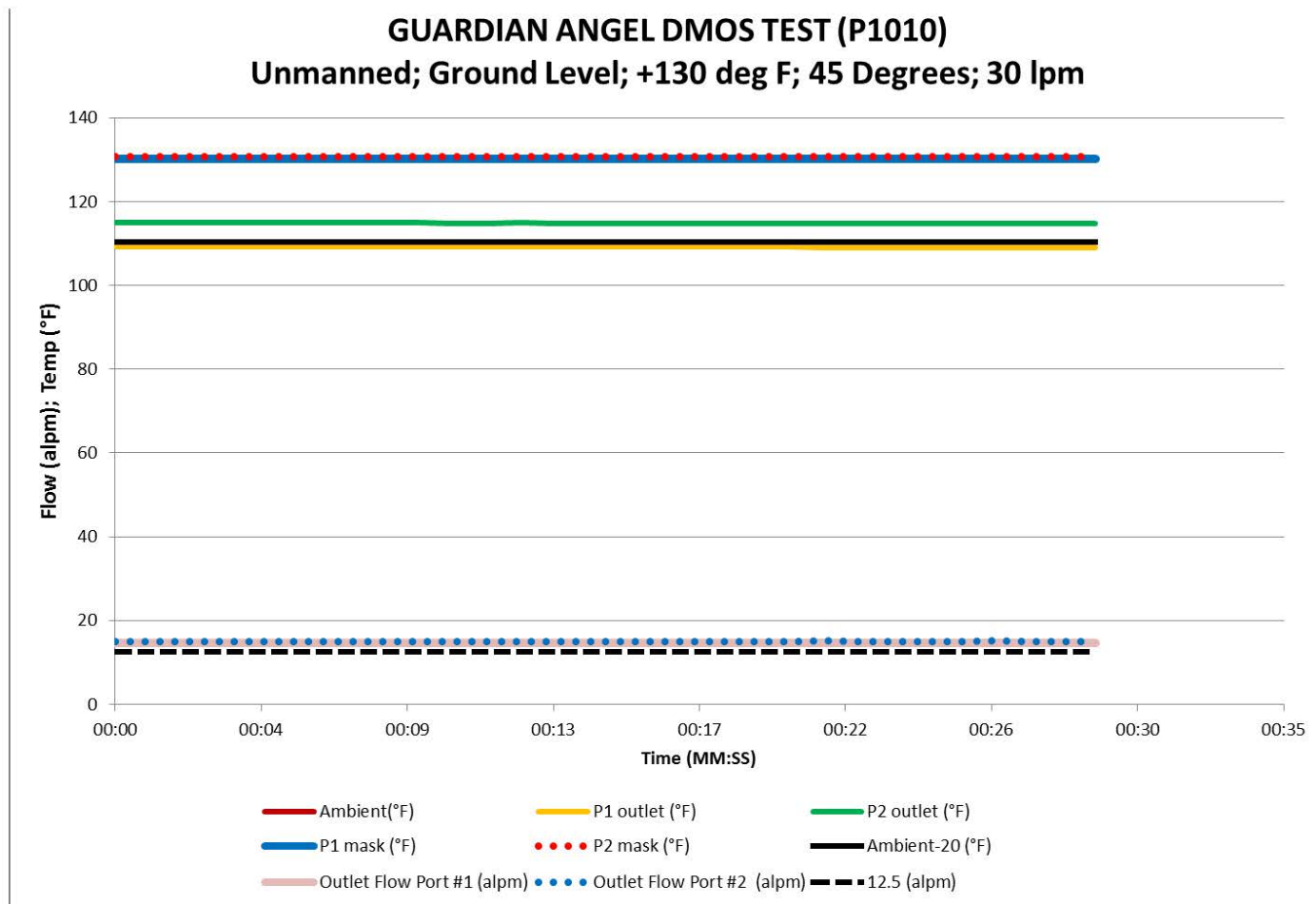


Figure D-61

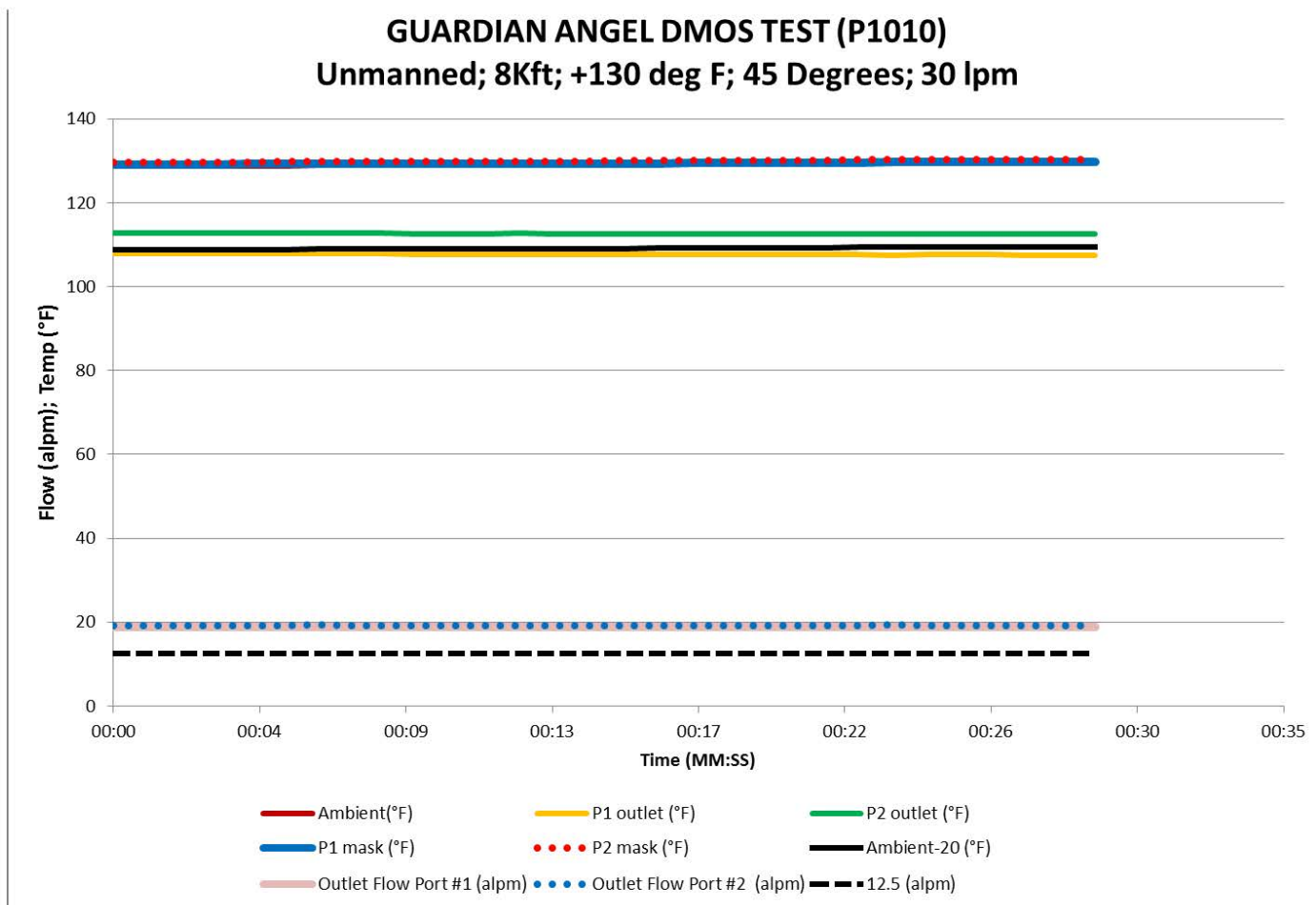


Figure D-62

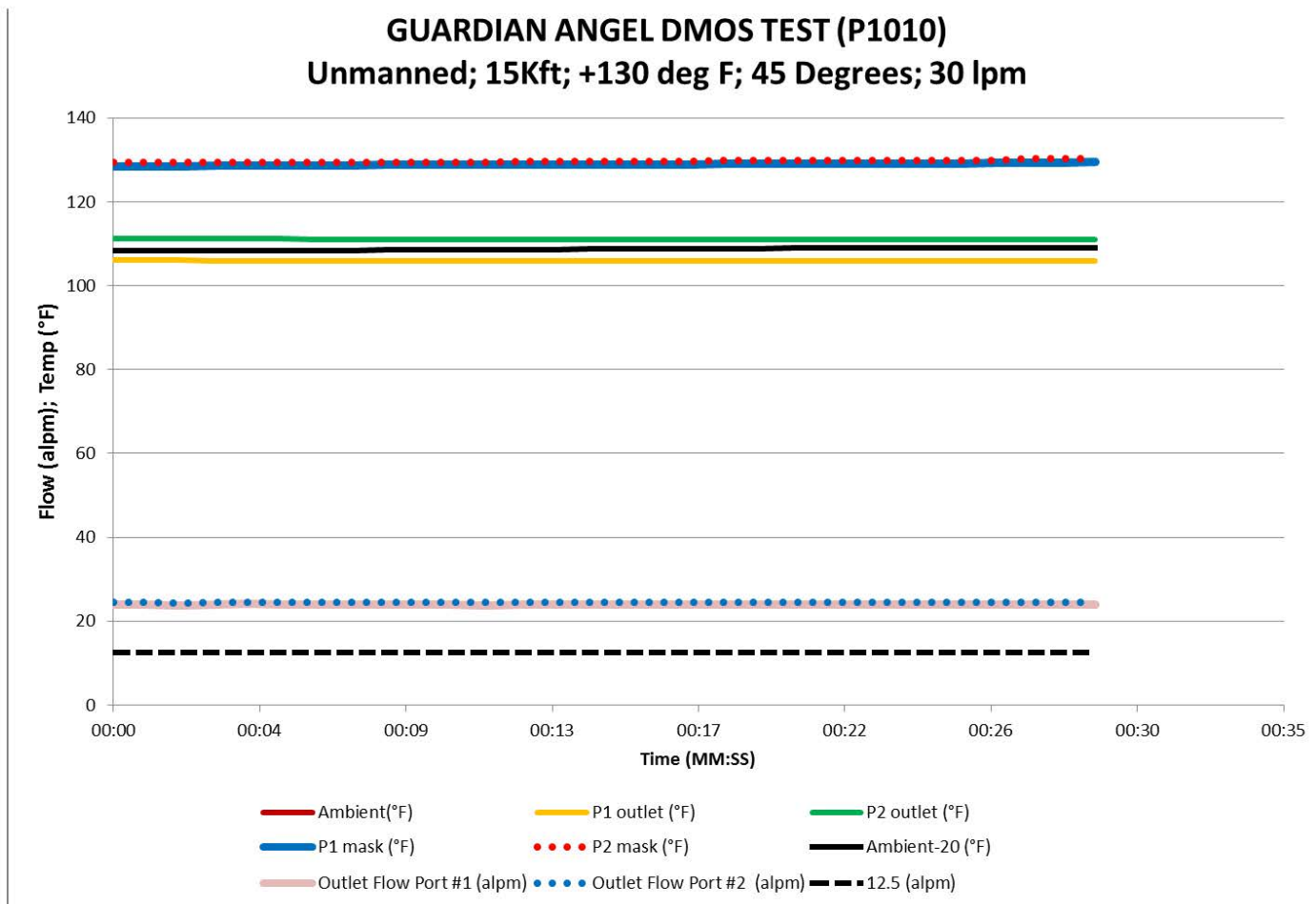


Figure D-63

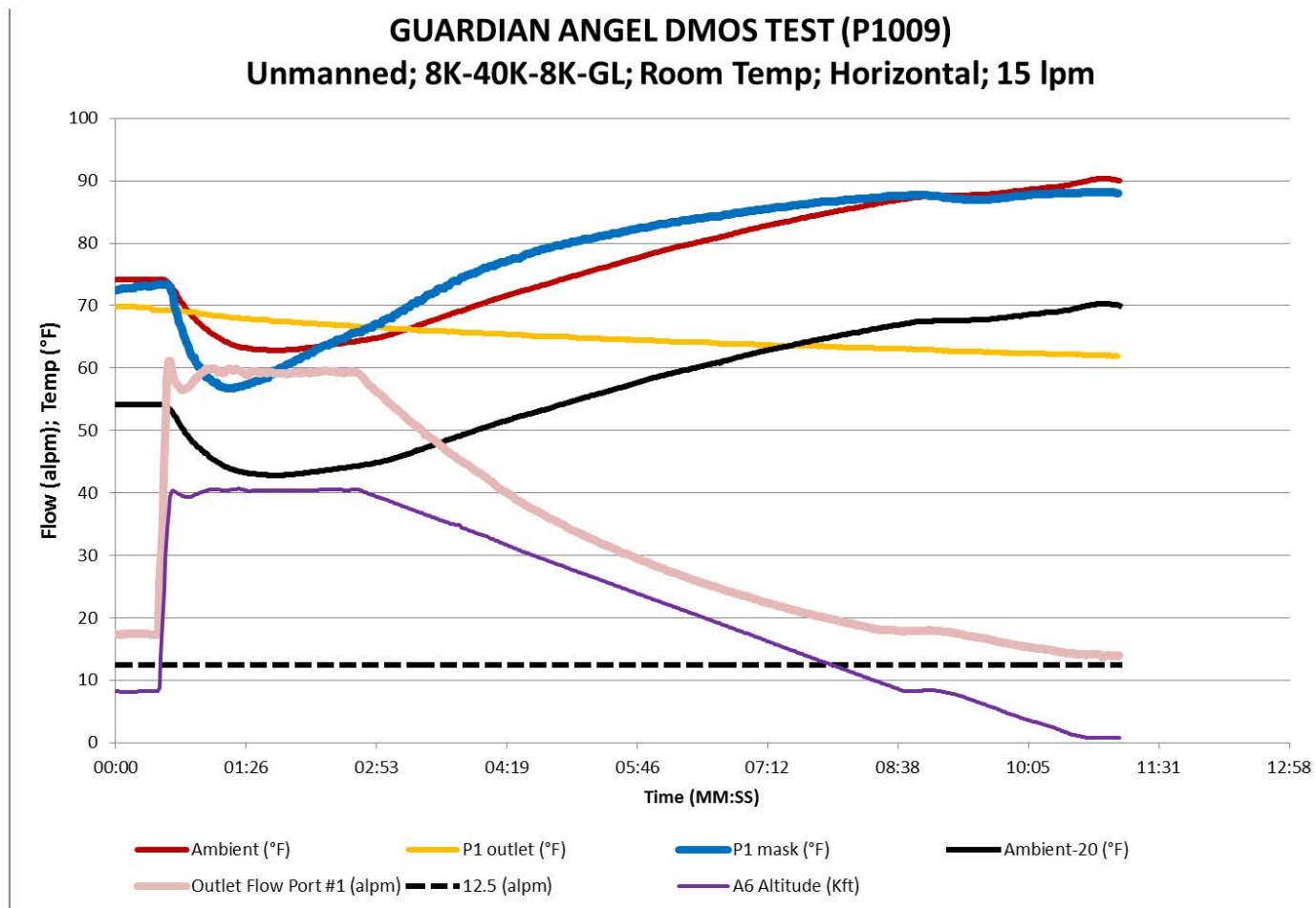


Figure D-64

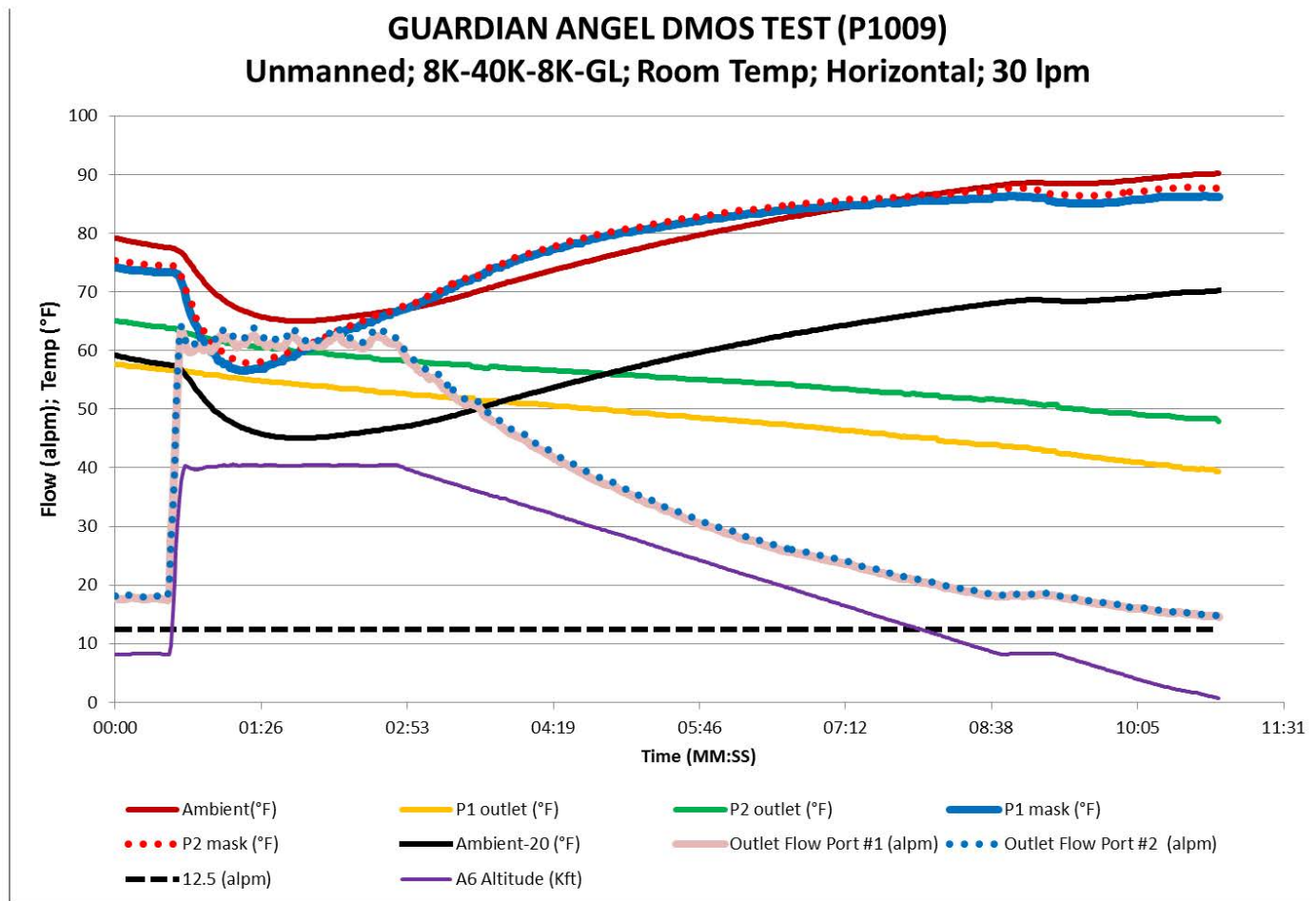


Figure D-65

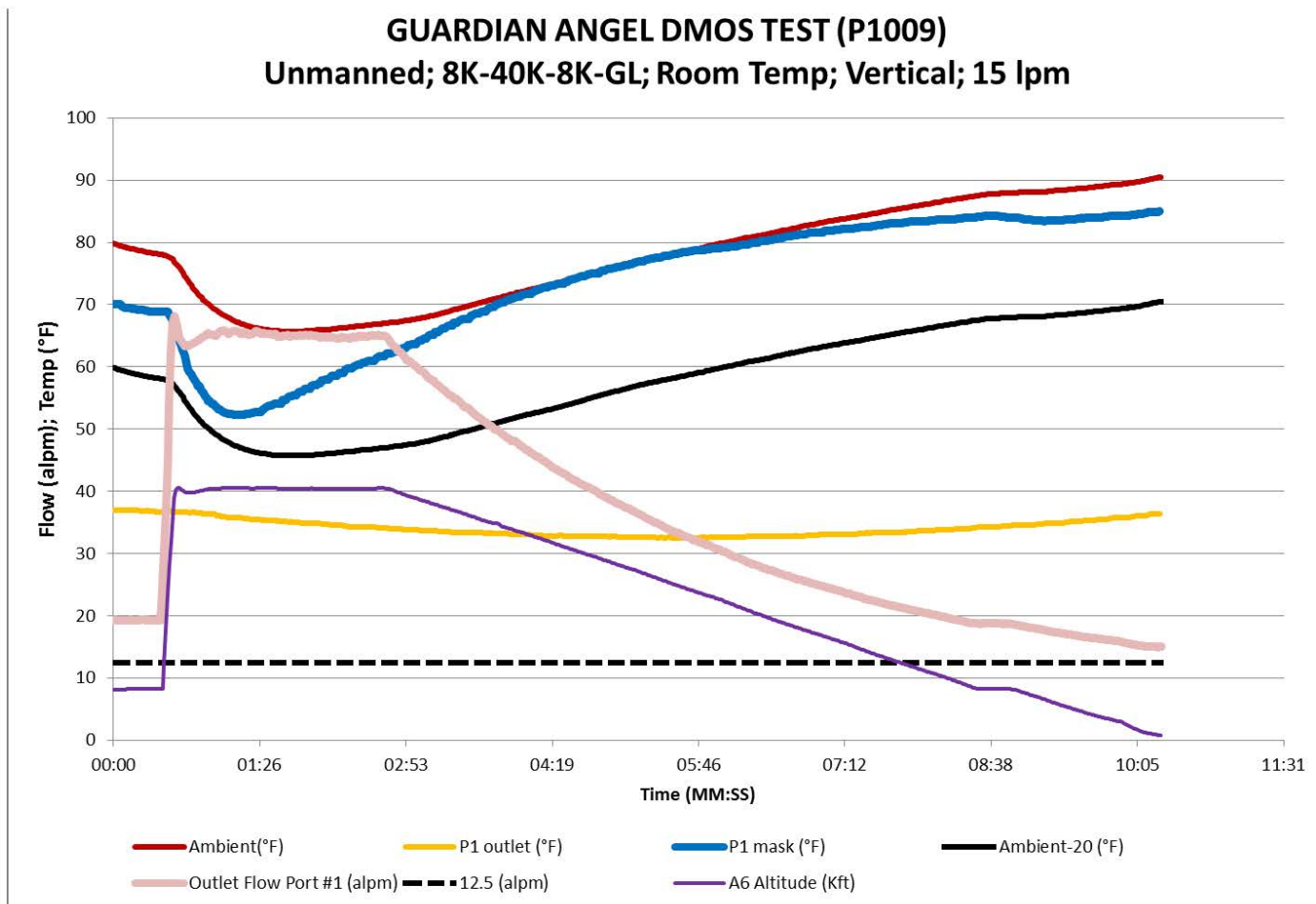


Figure D-66

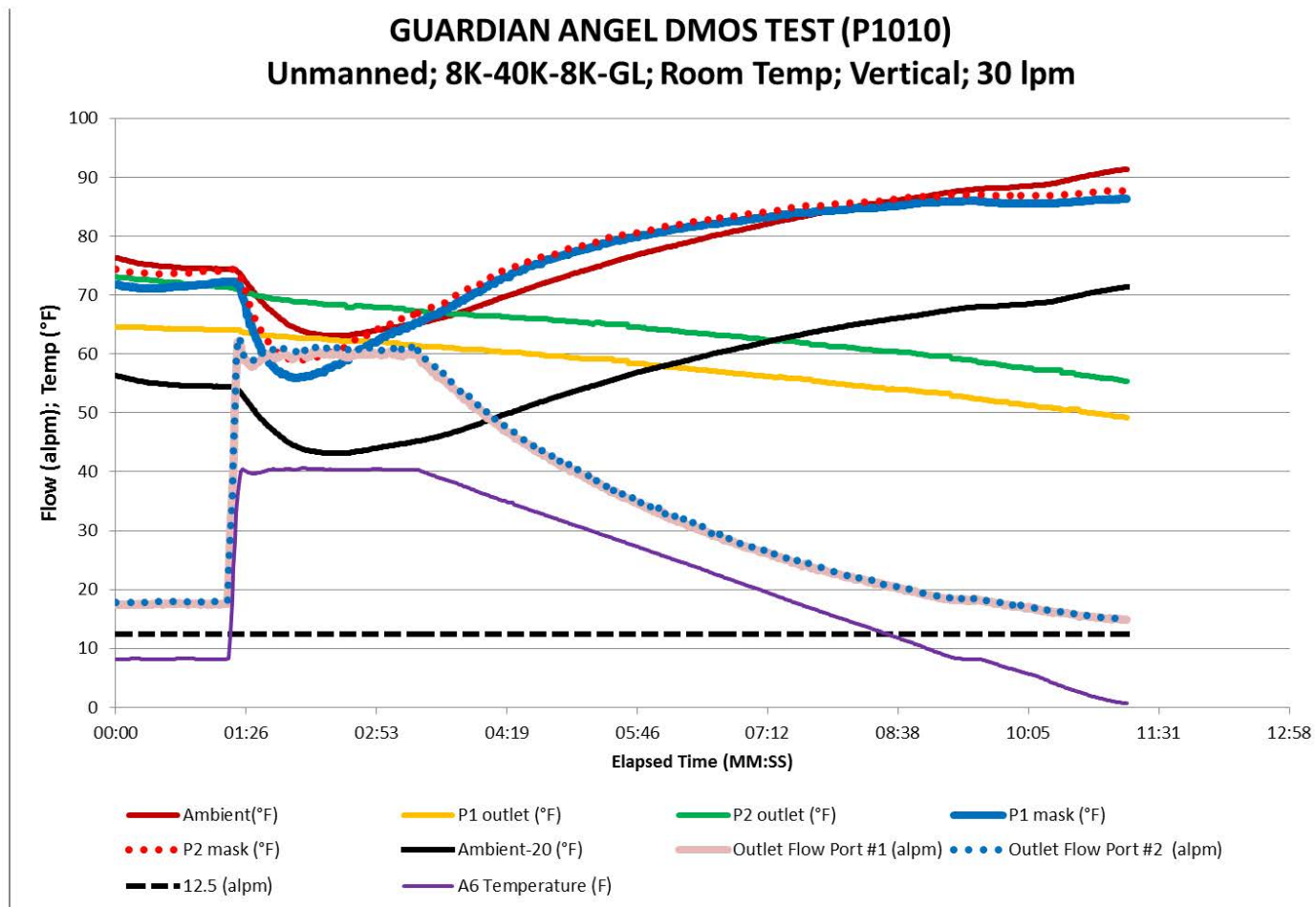


Figure D-67

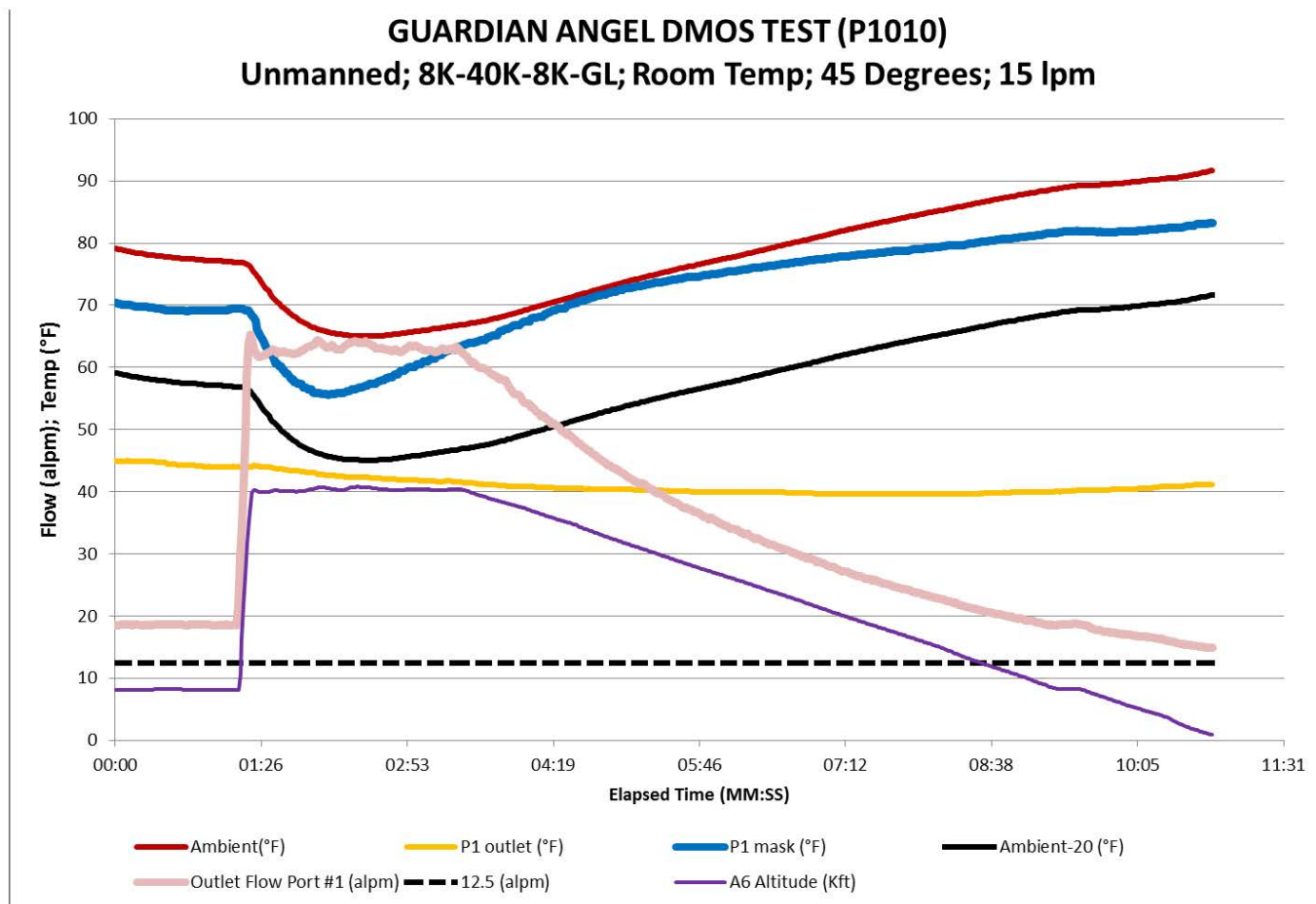


Figure D-68

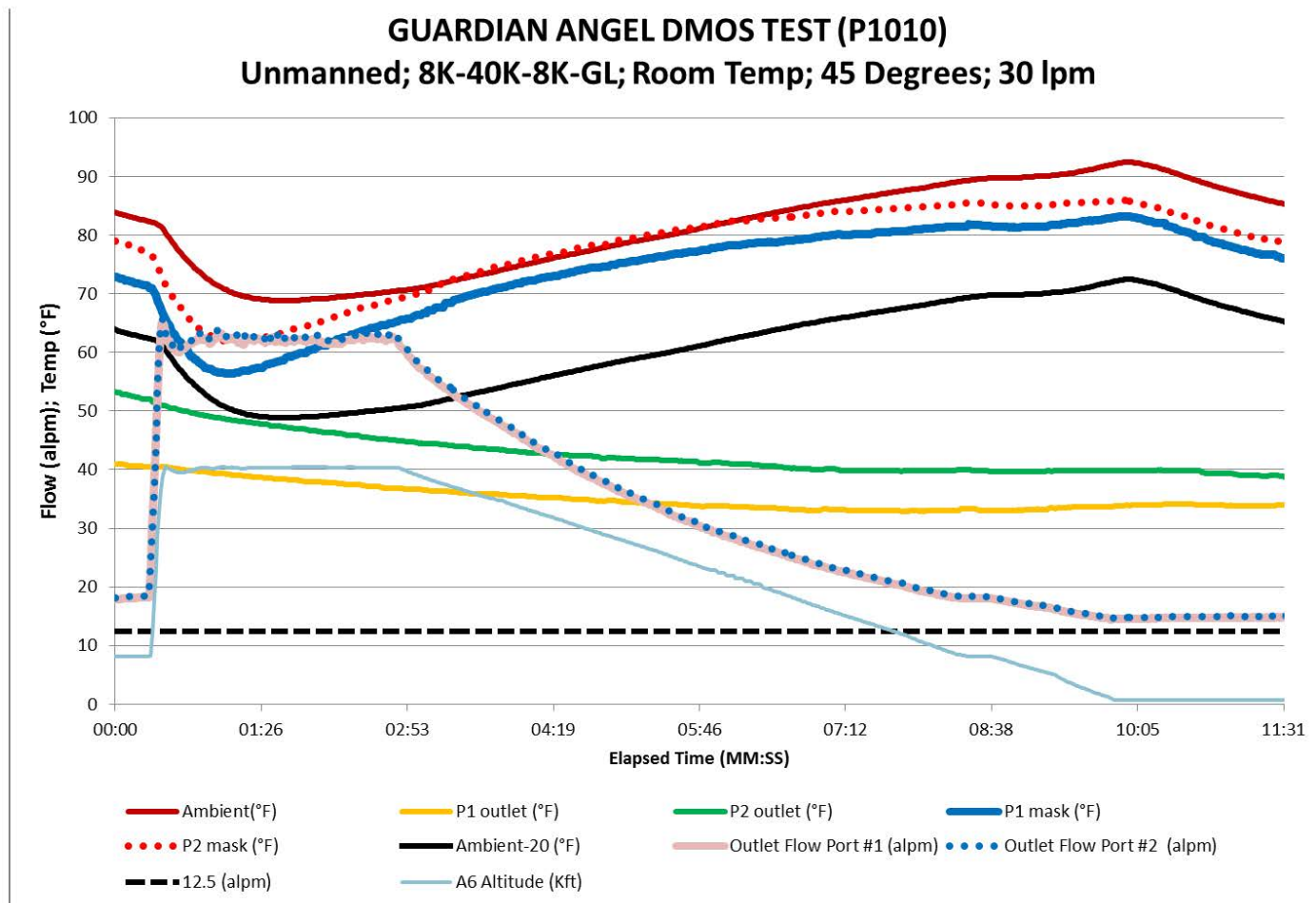


Figure D-69

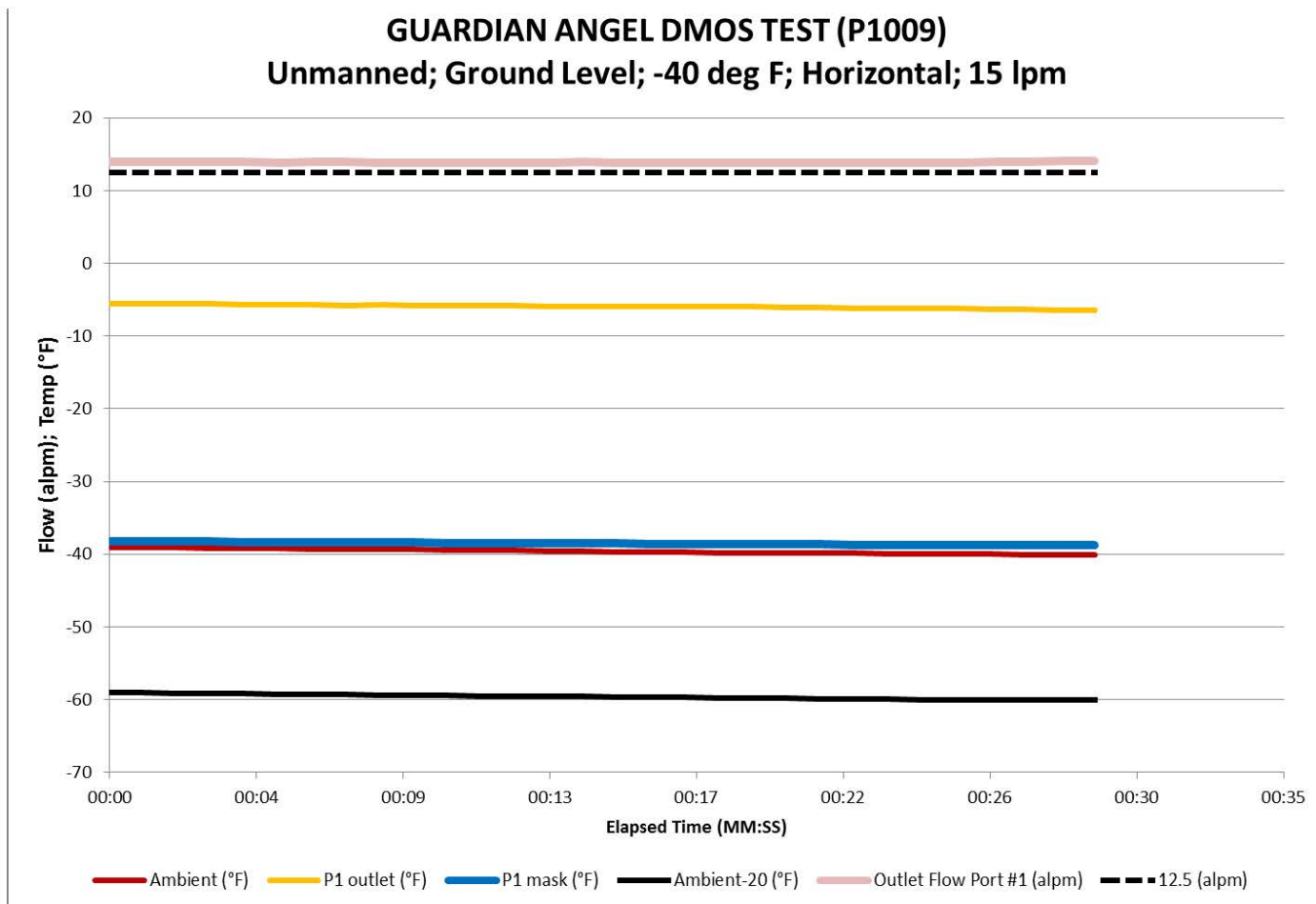


Figure D-70

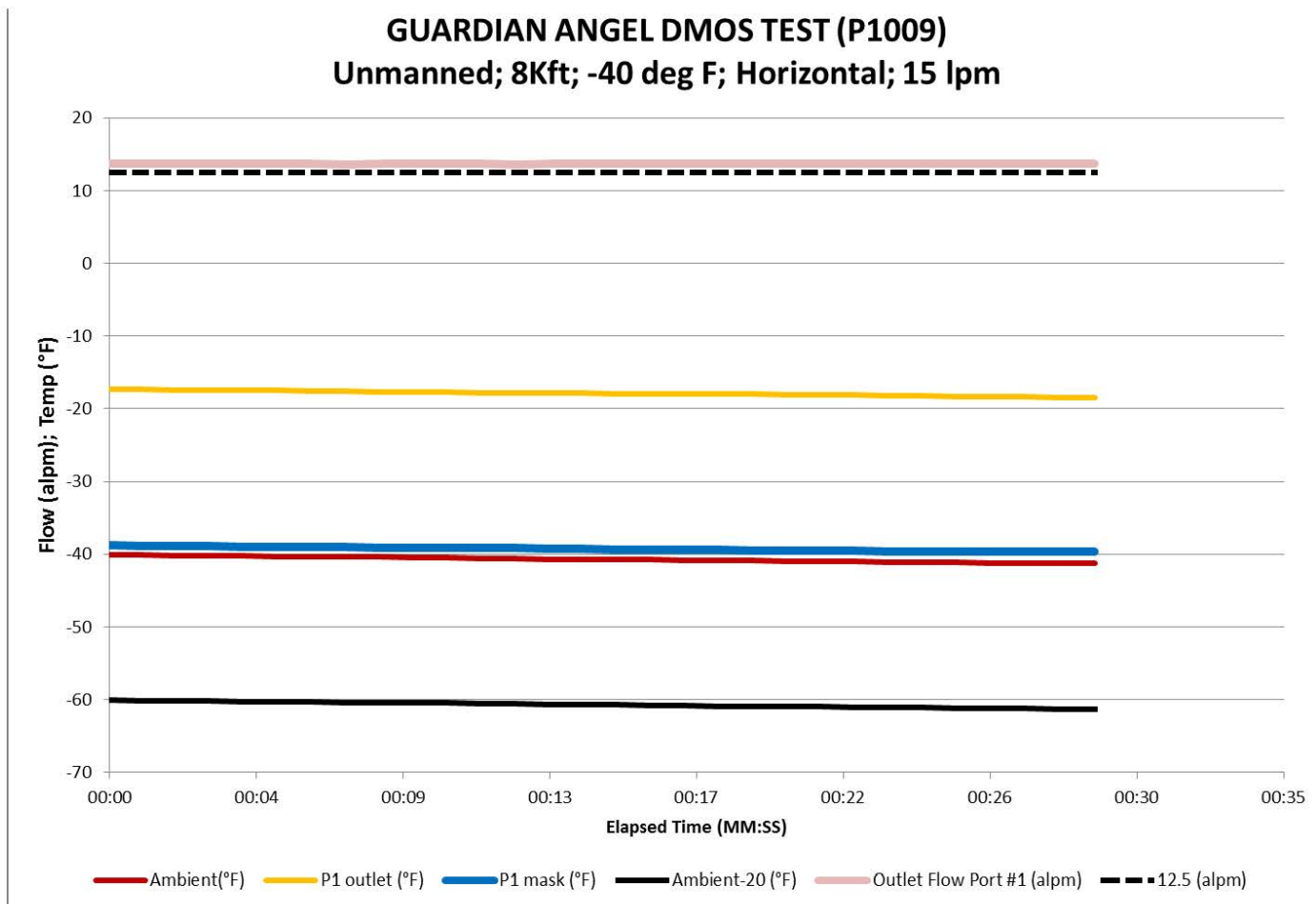


Figure D-71

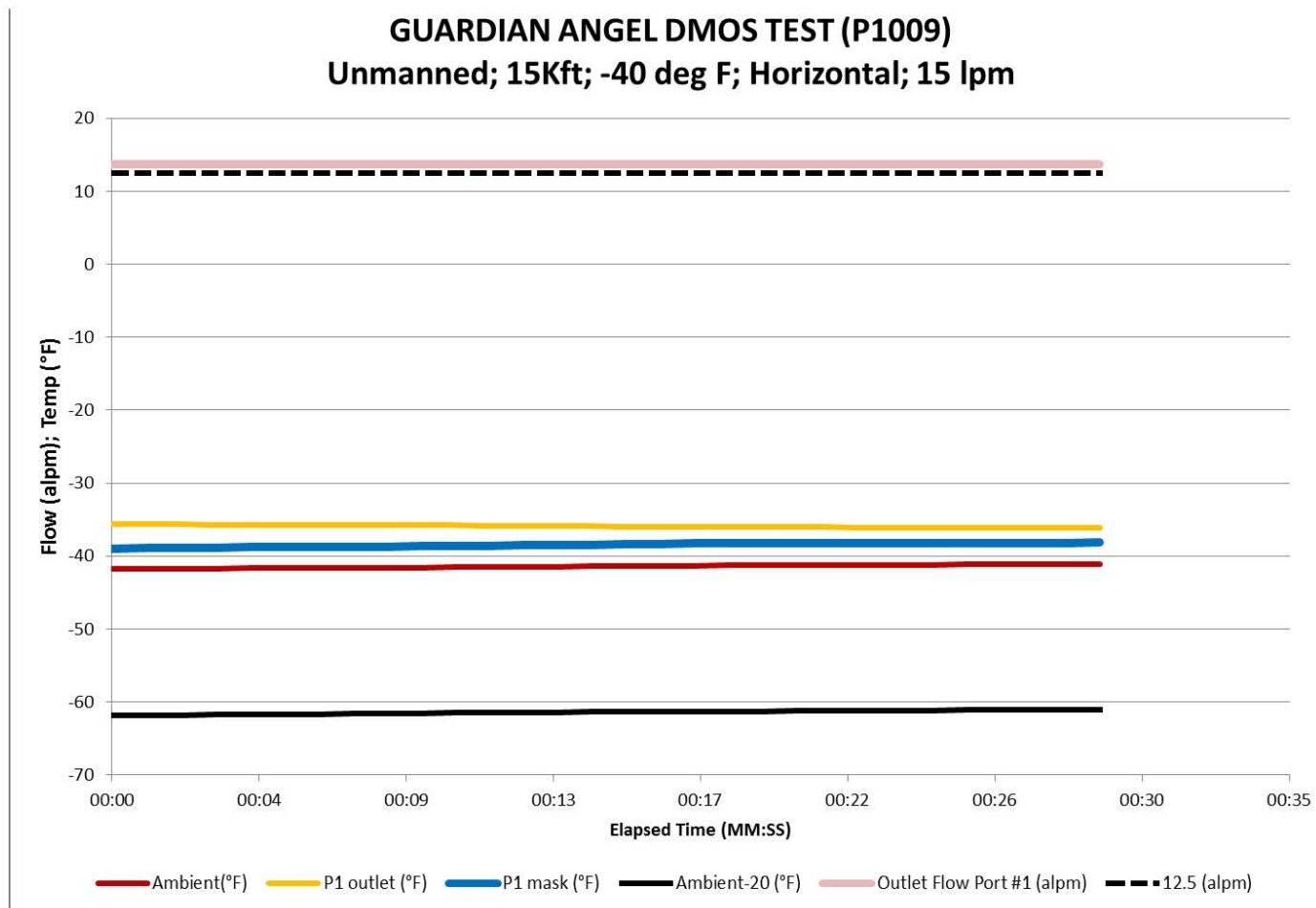


Figure D-72

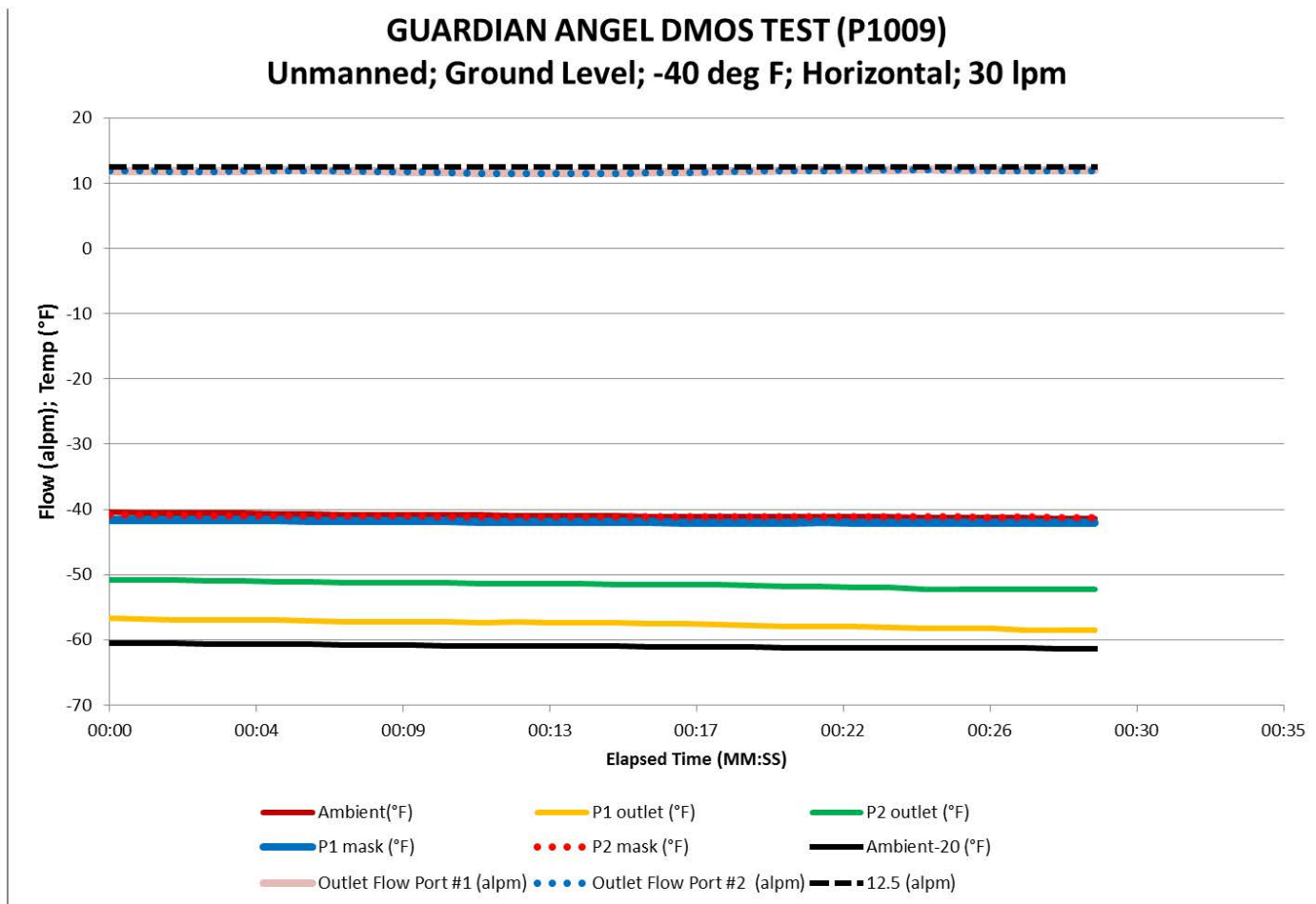


Figure D-73

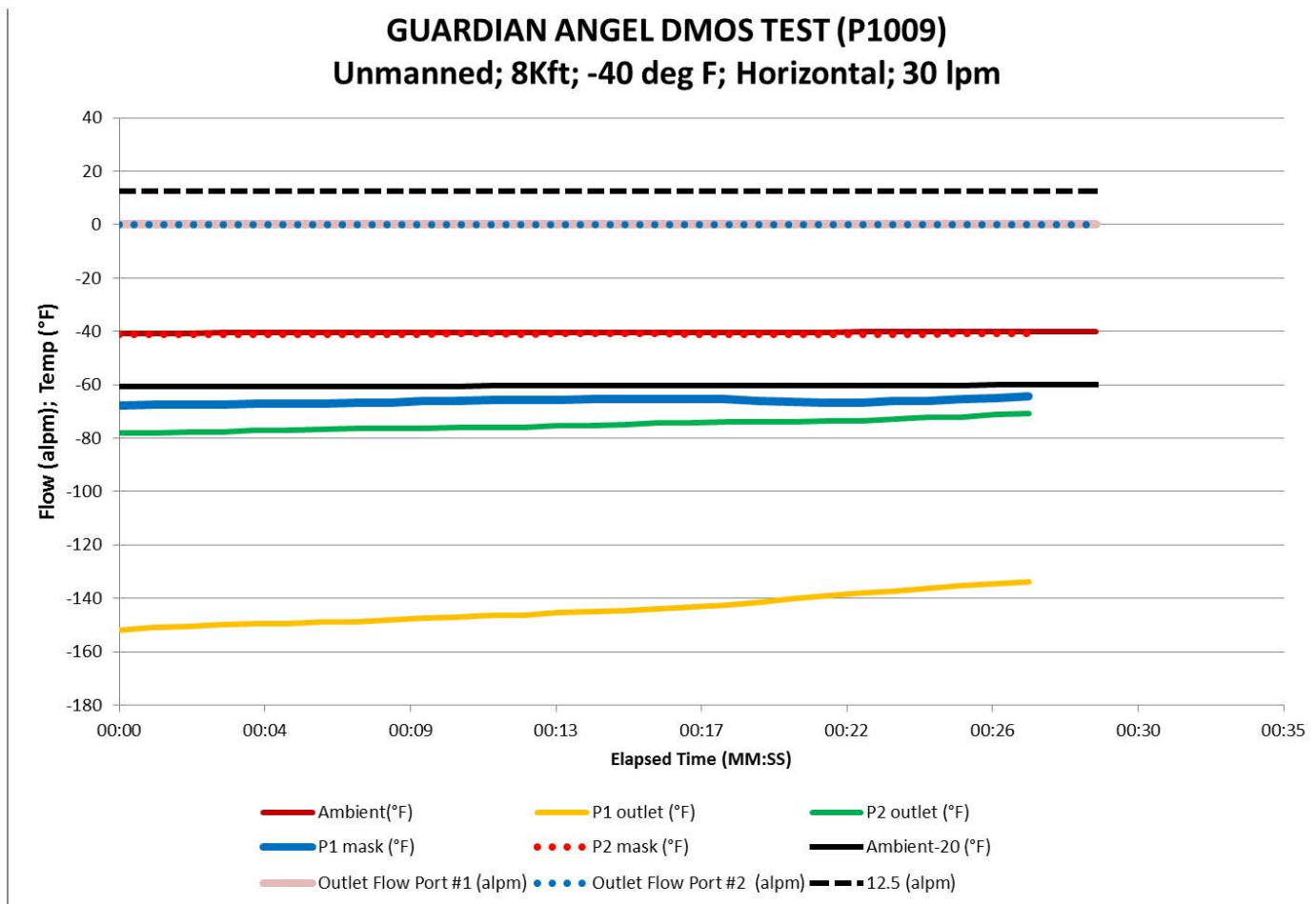


Figure D-74

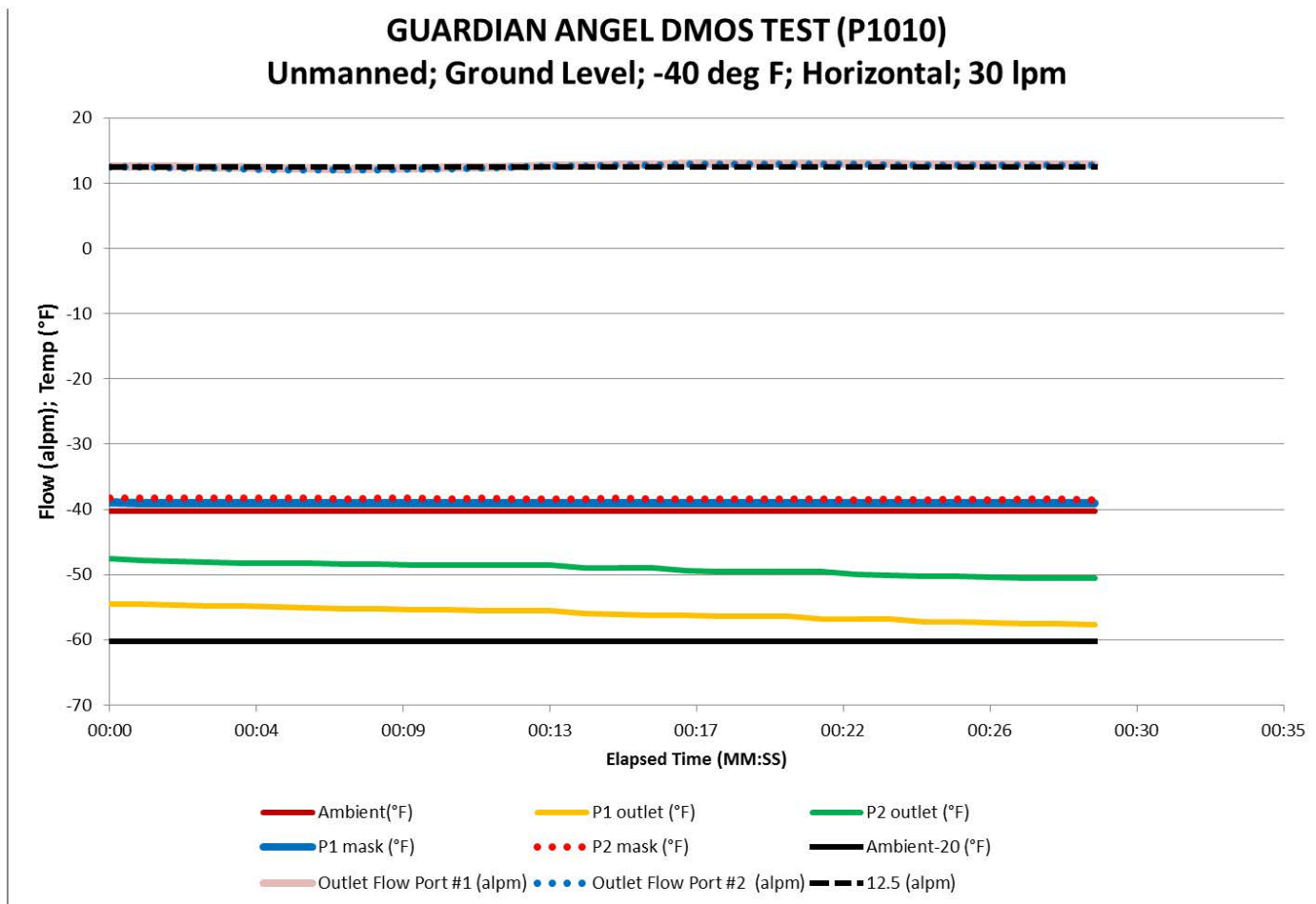


Figure D-75

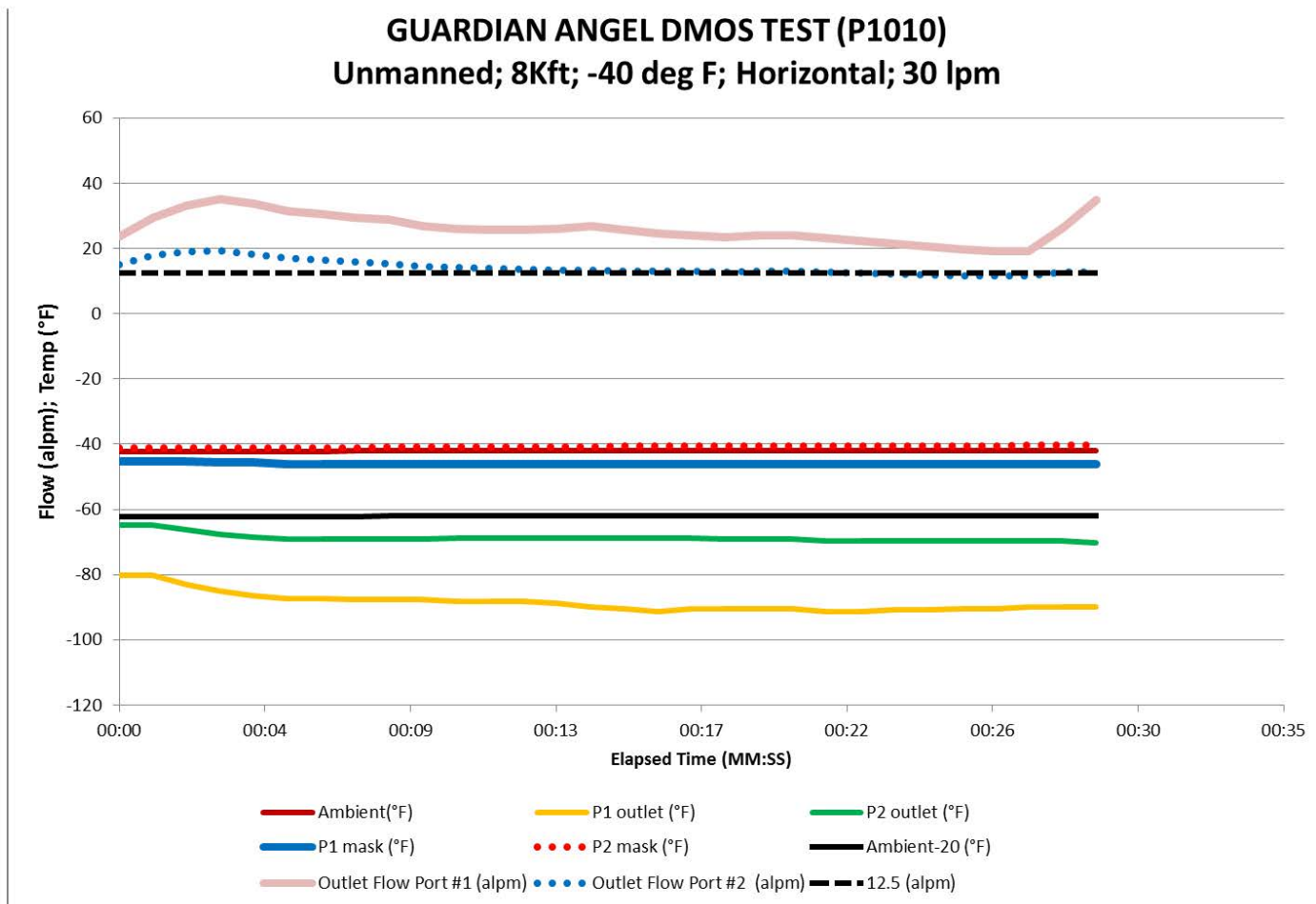


Figure D-76

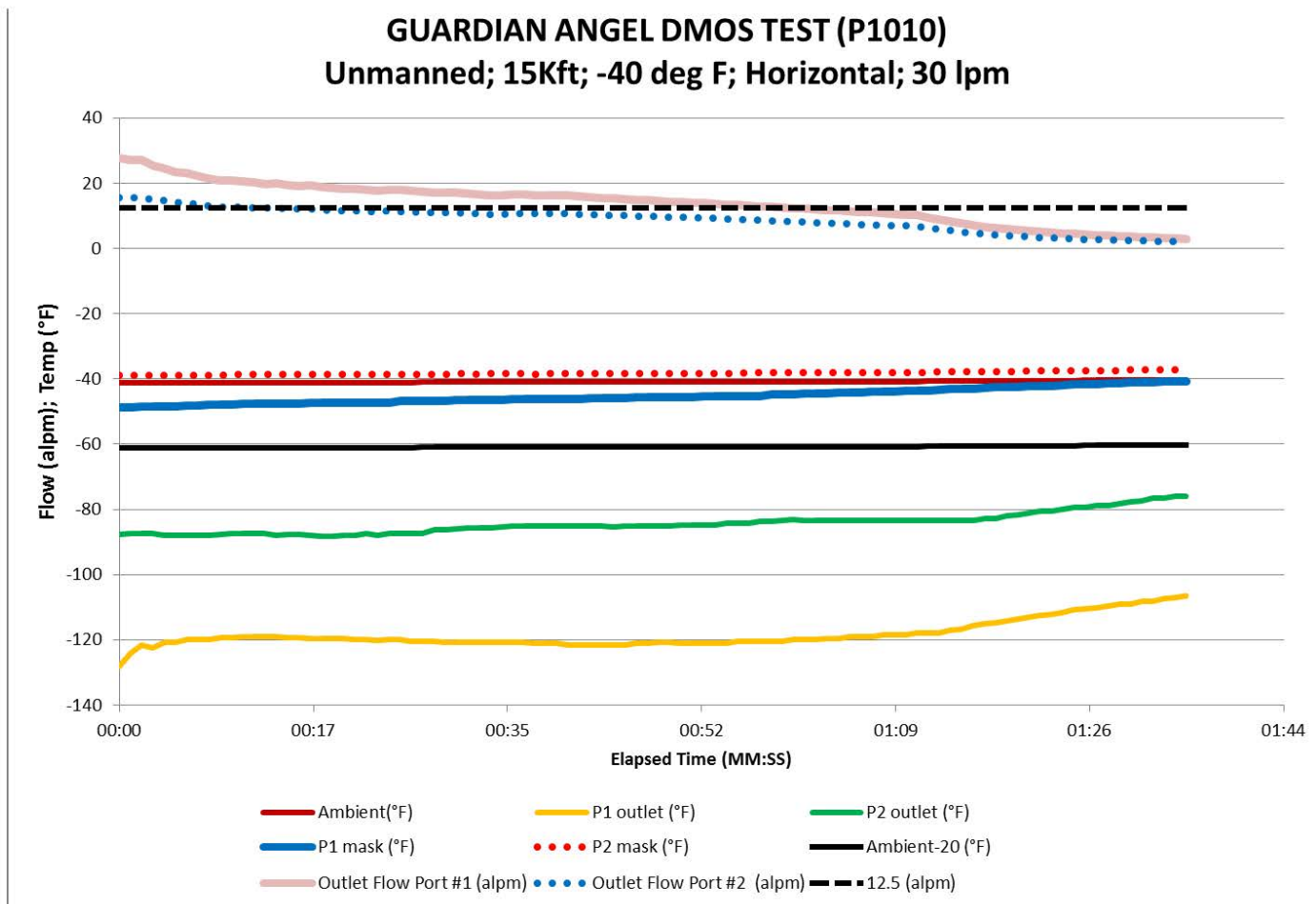


Figure D-77

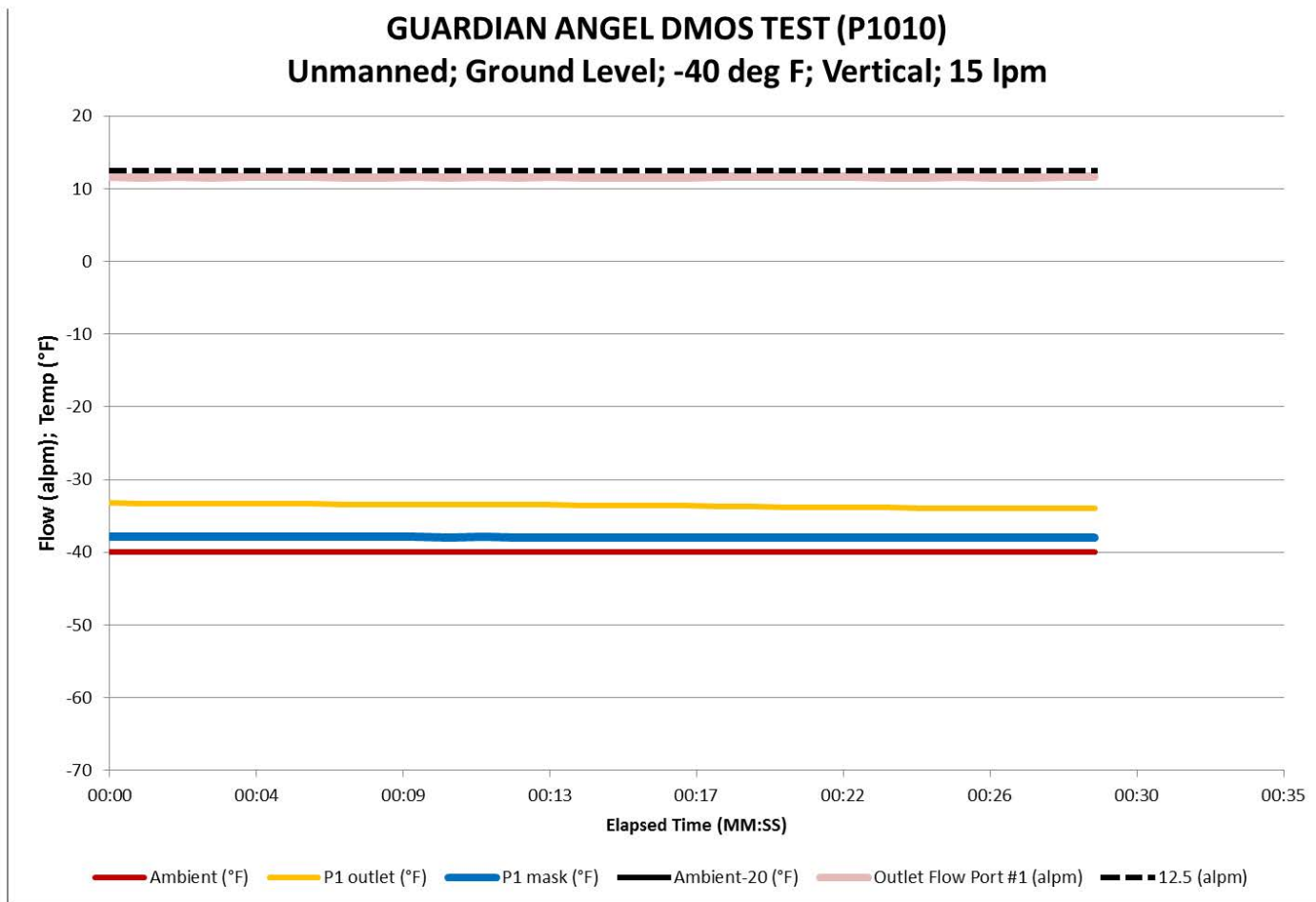


Figure D-78

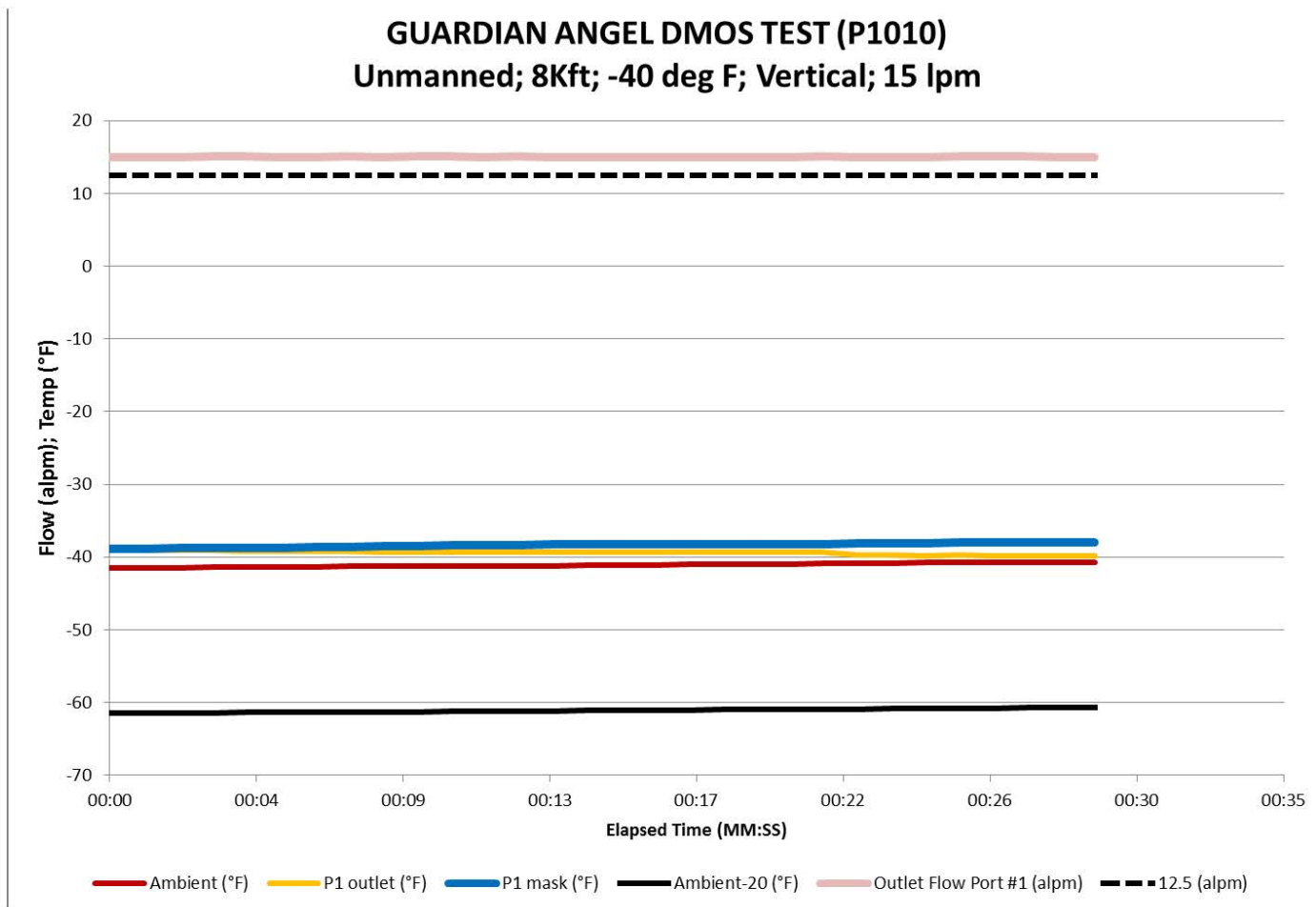


Figure D-79

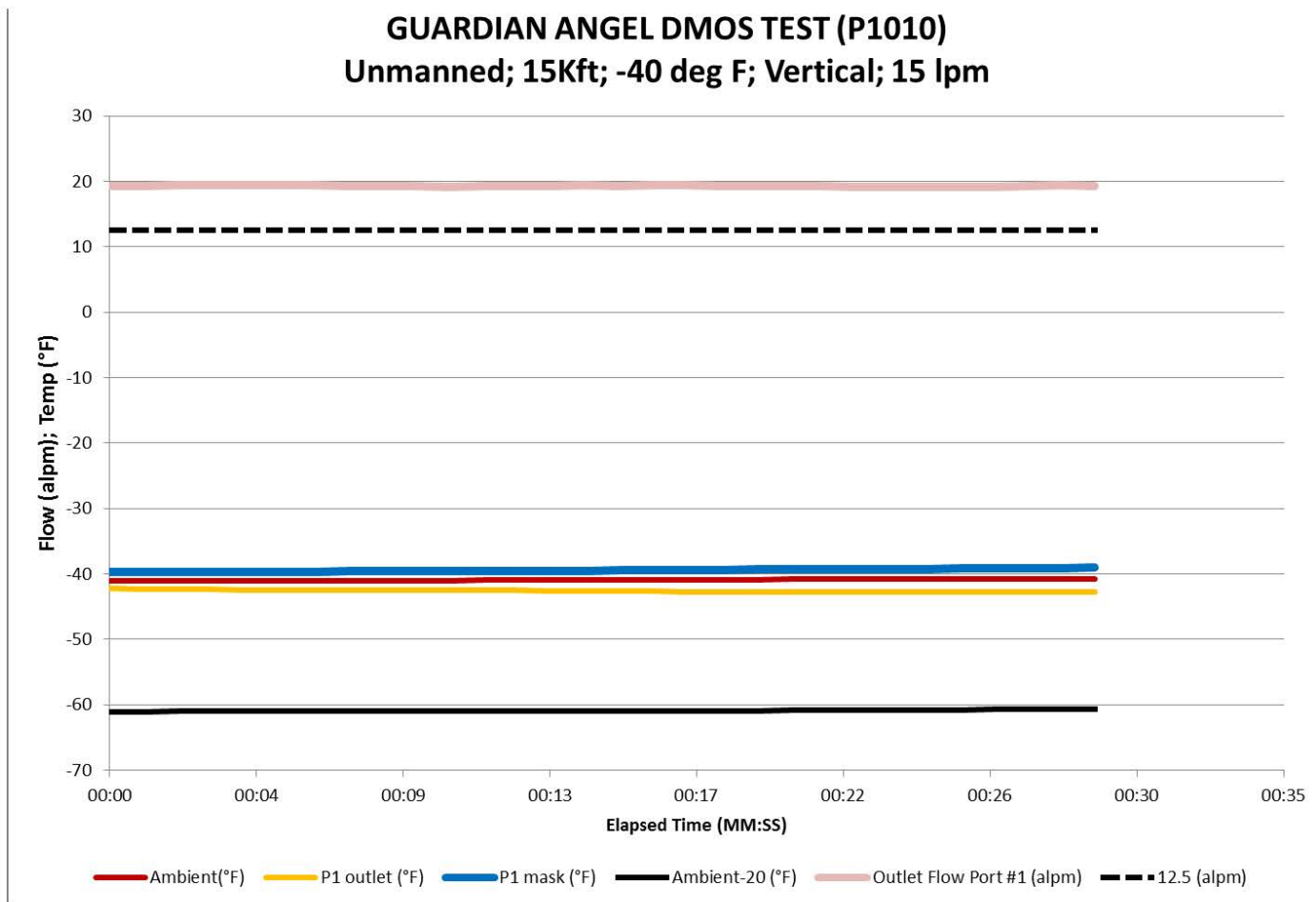


Figure D-80

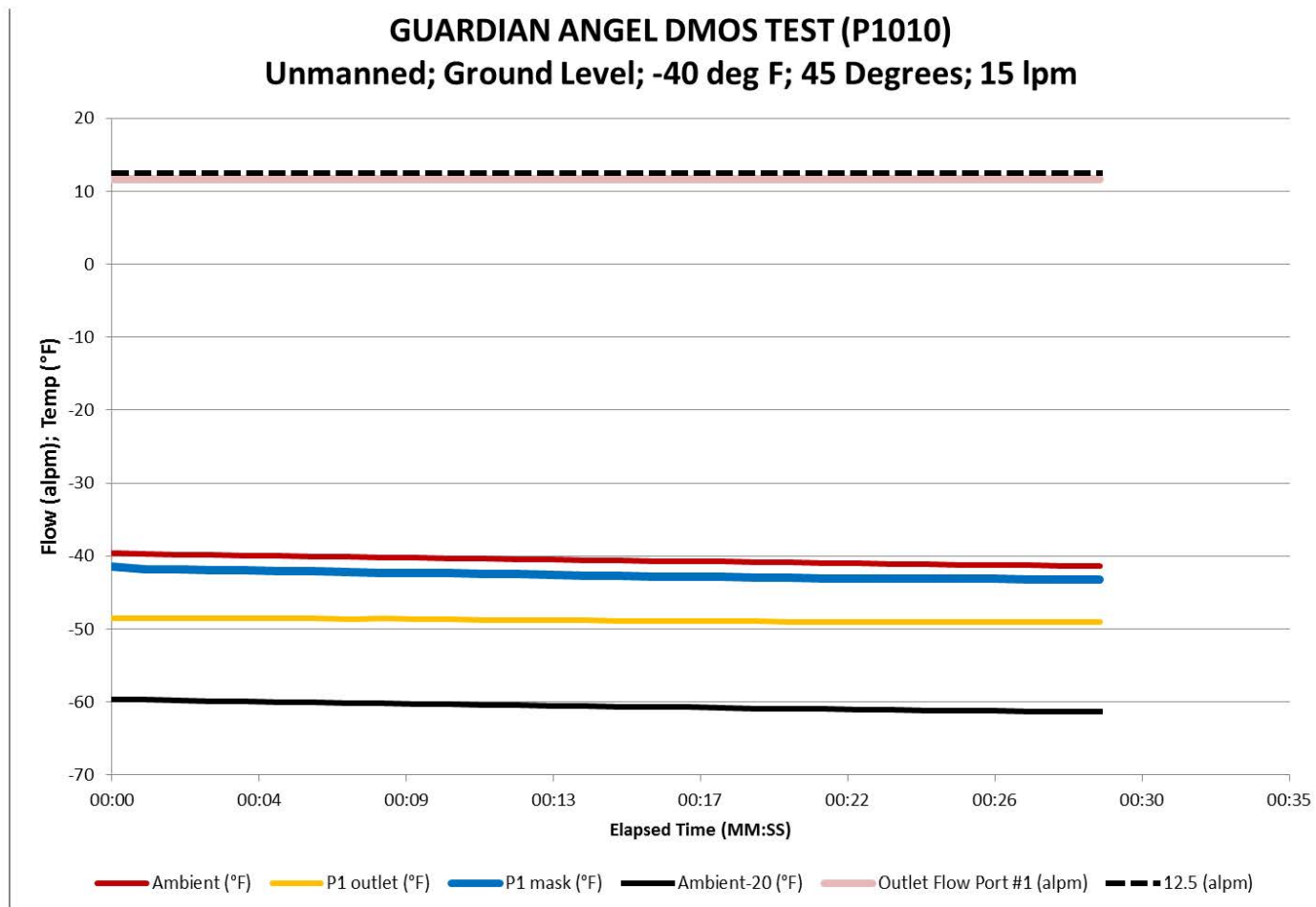


Figure D-81

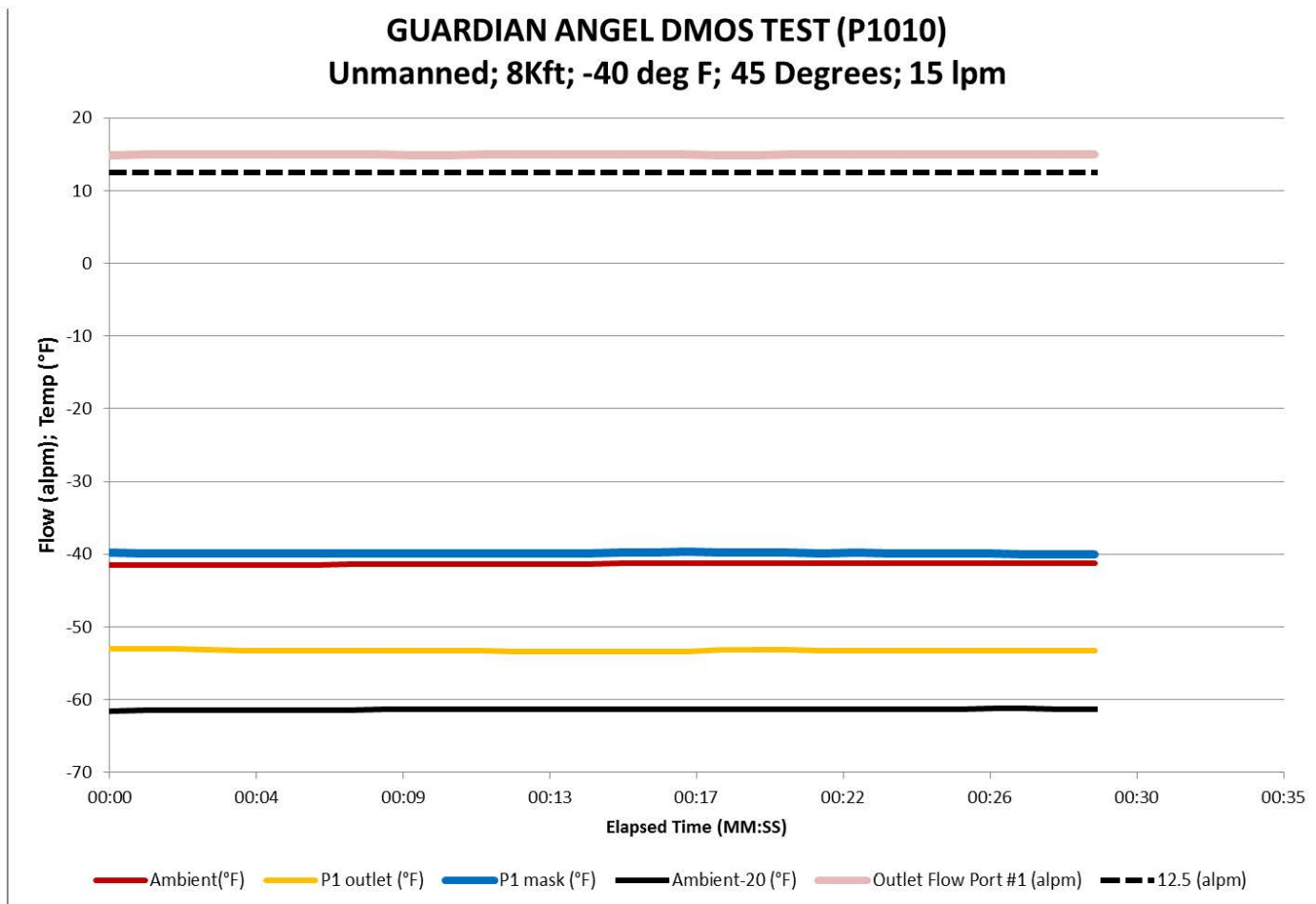


Figure D-82

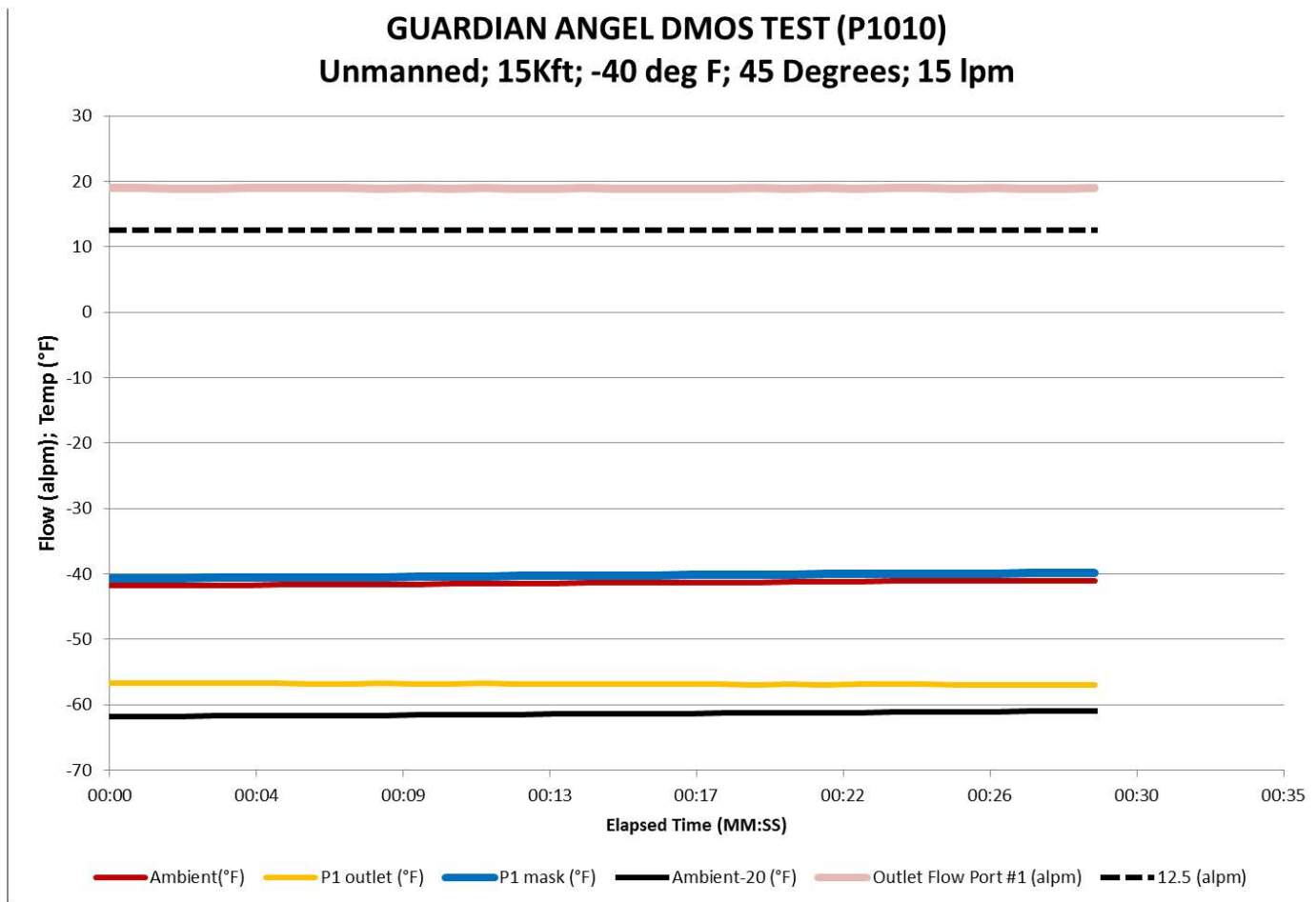


Figure D-83

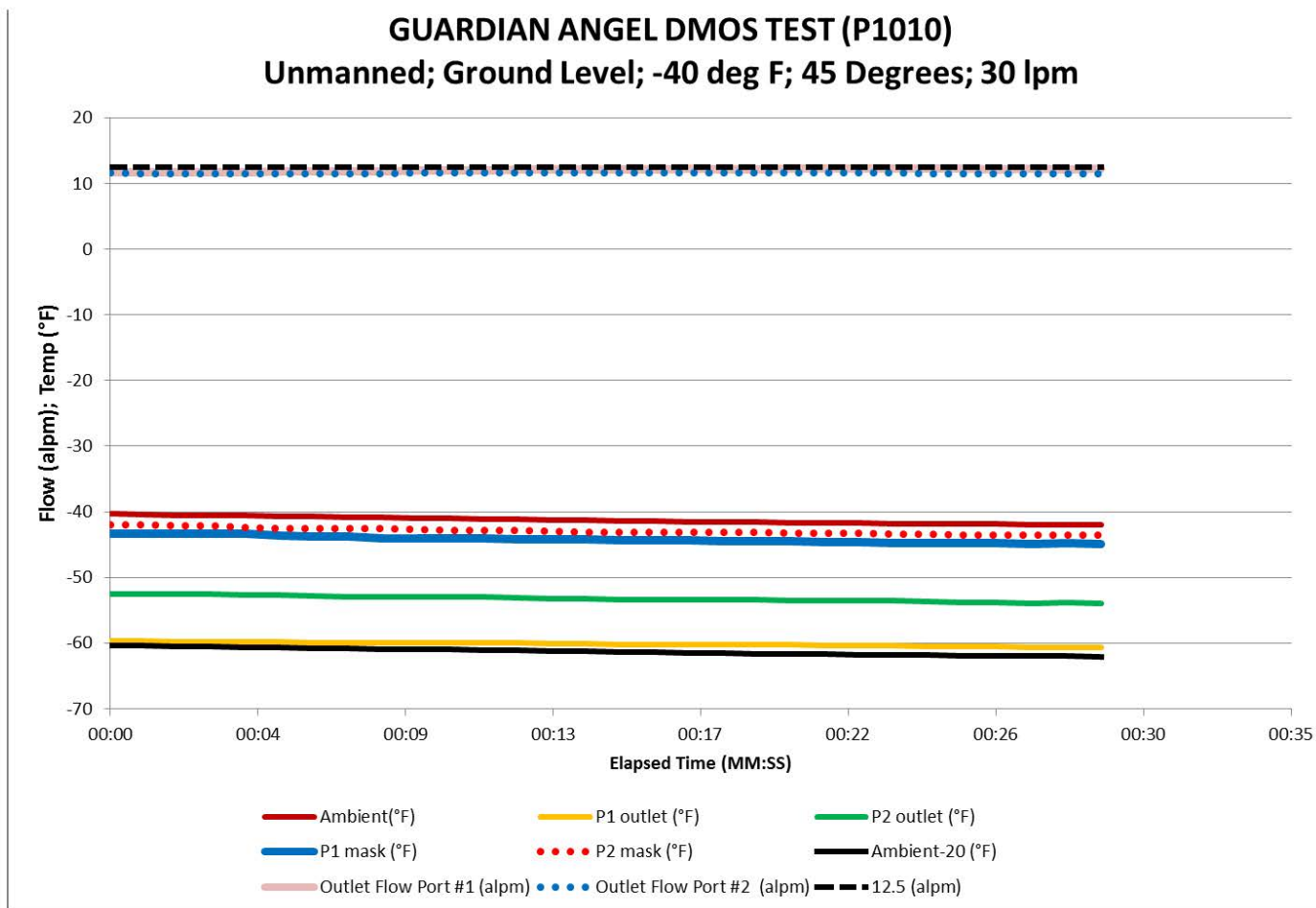


Figure D-84

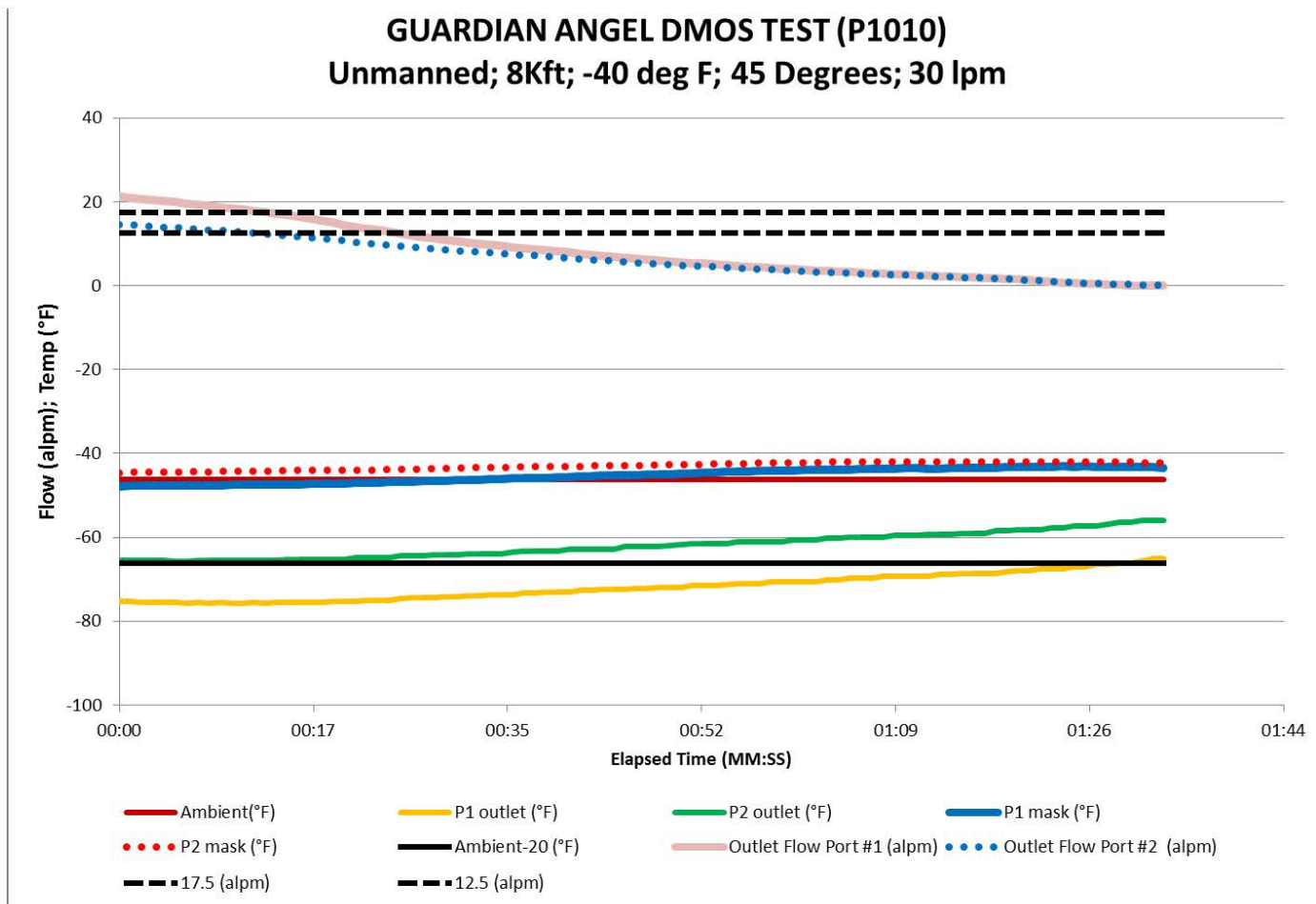


Figure D-85

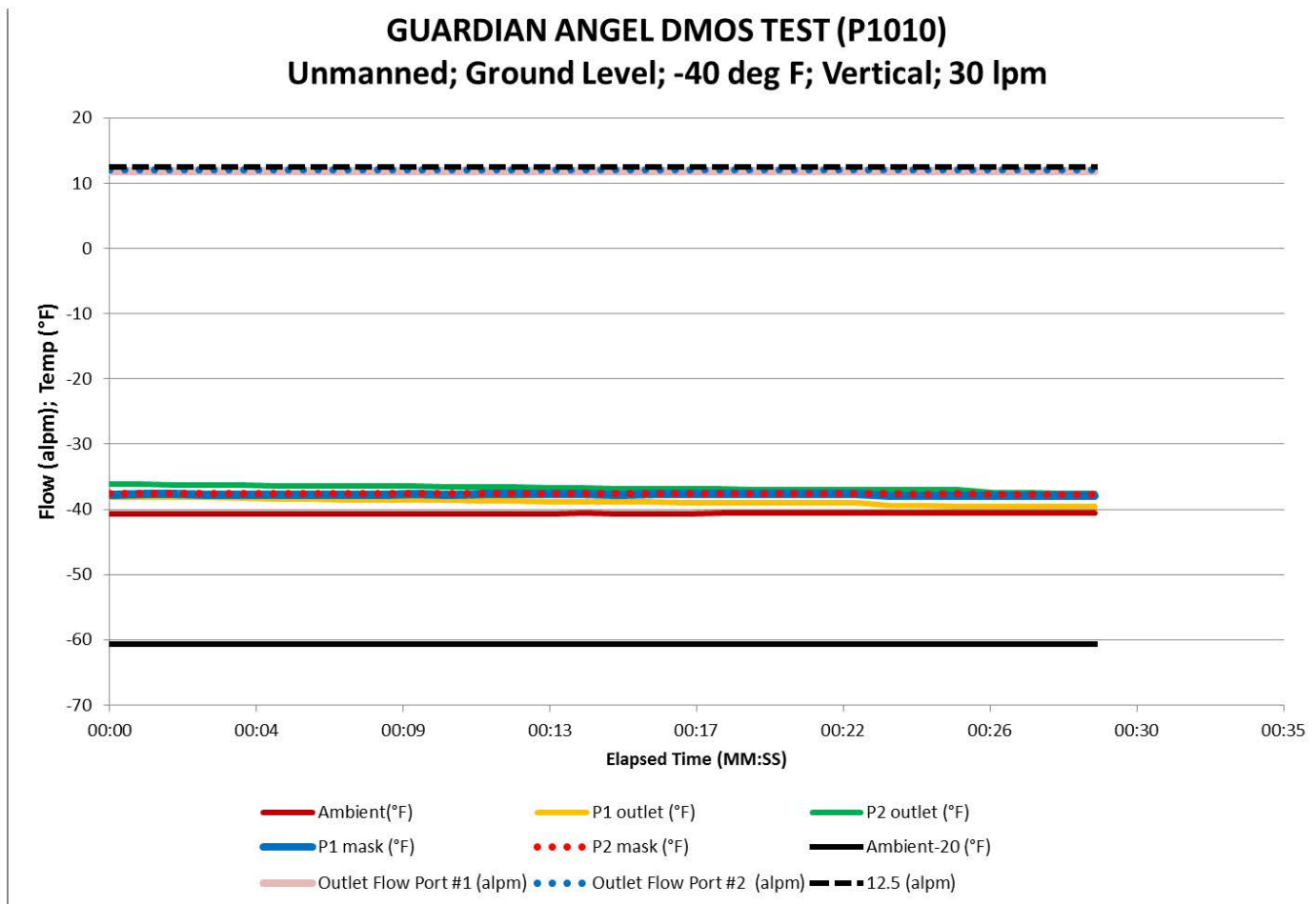


Figure D-86

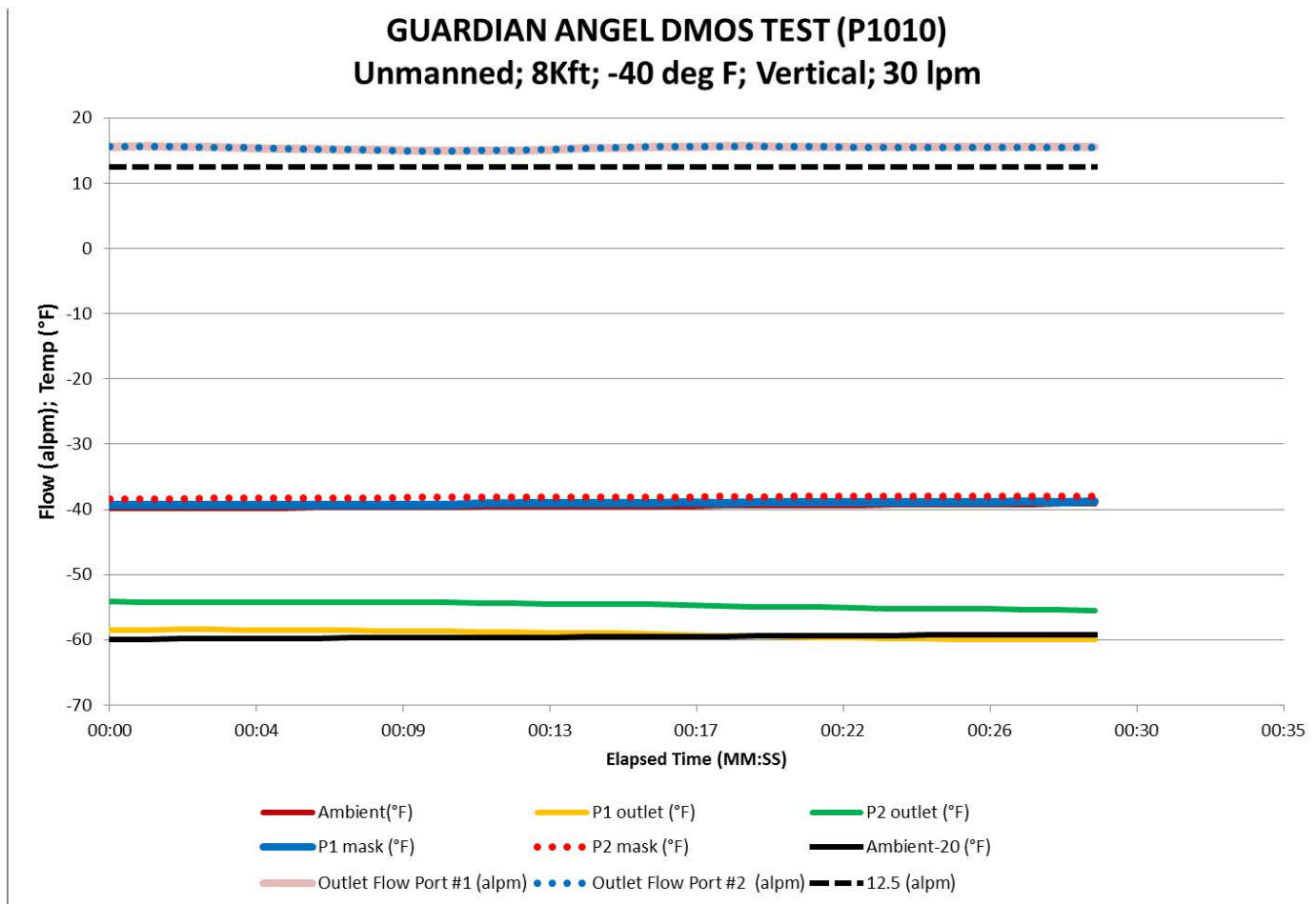


Figure D-87

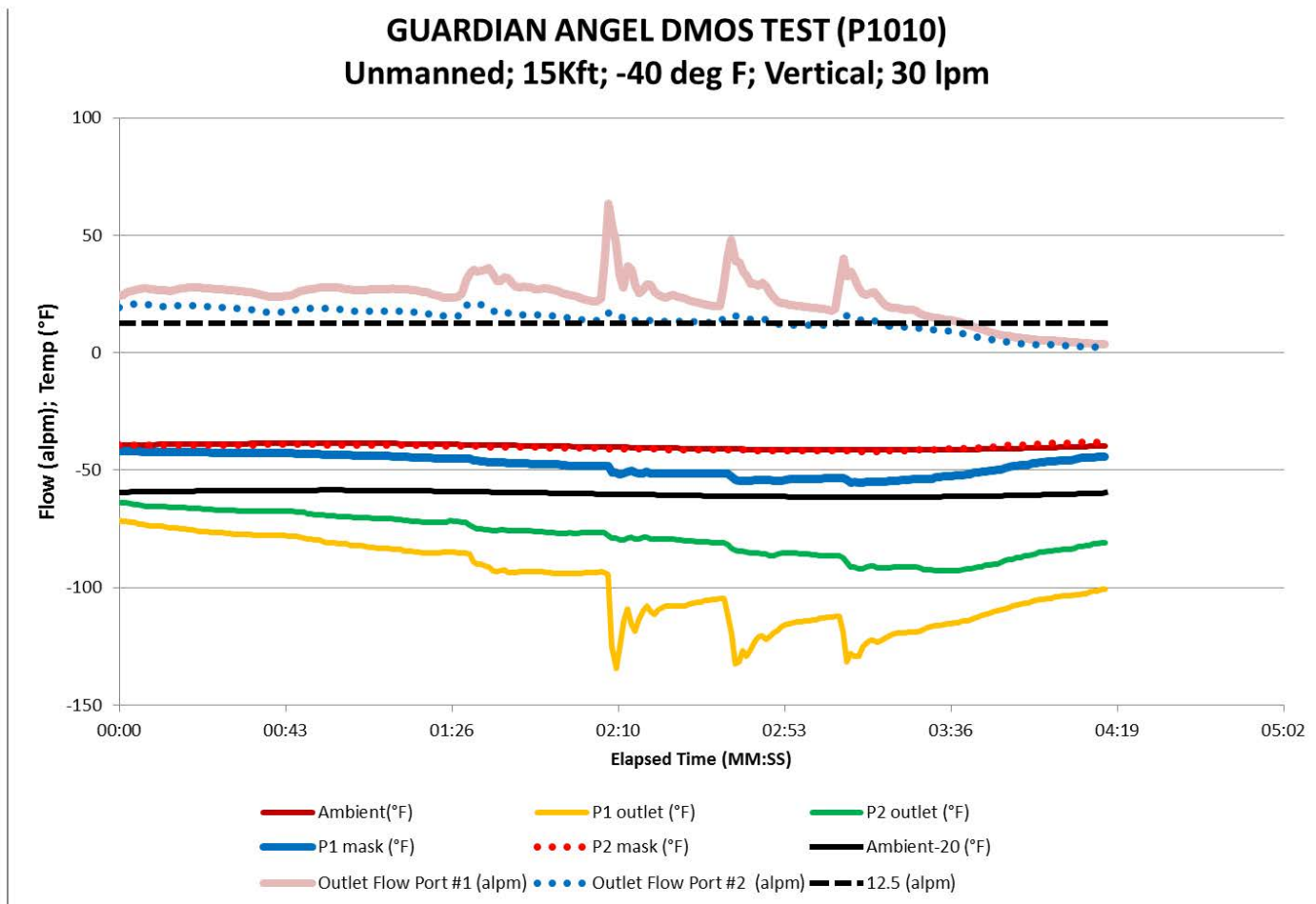


Figure D-88

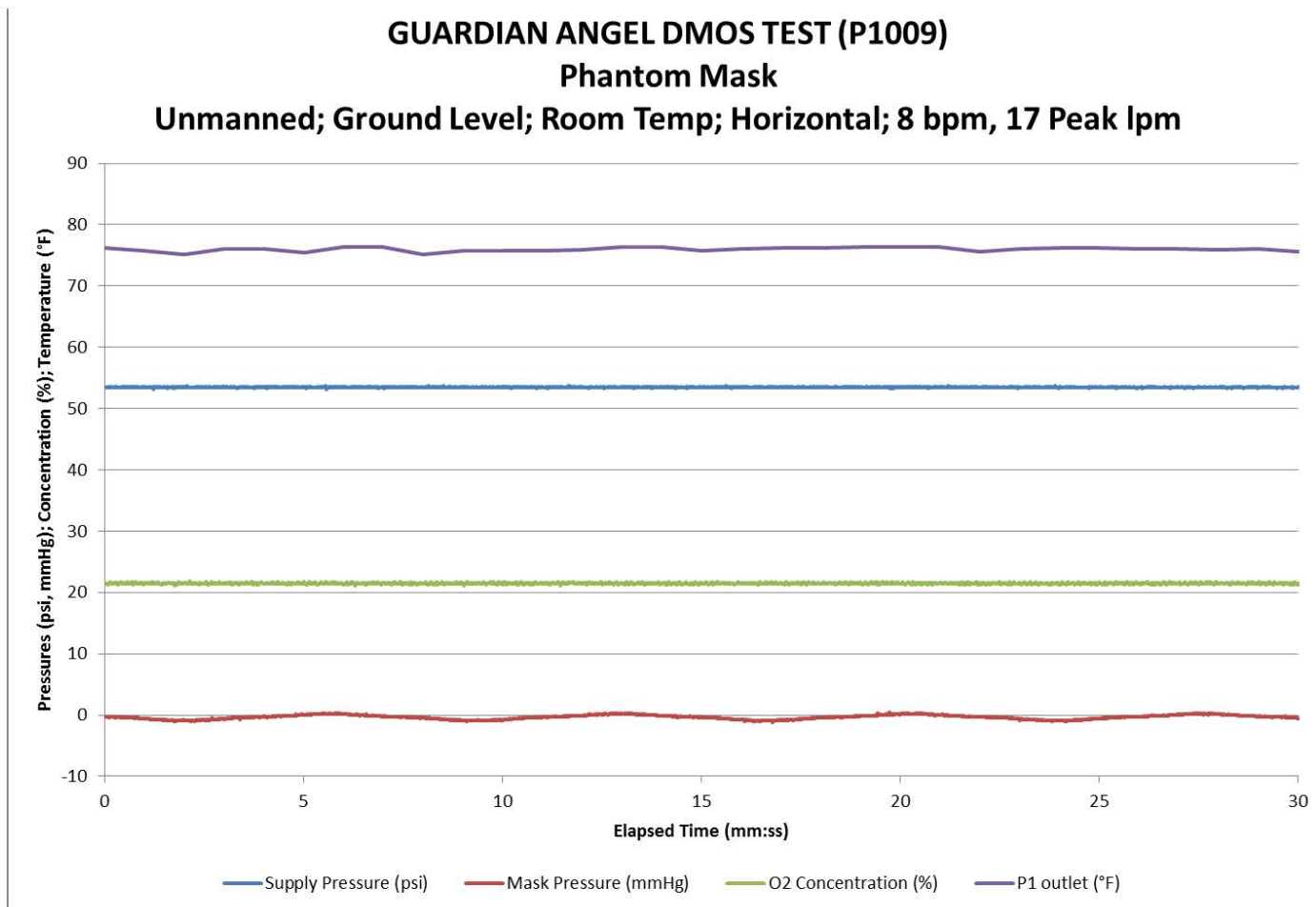


Figure D-89

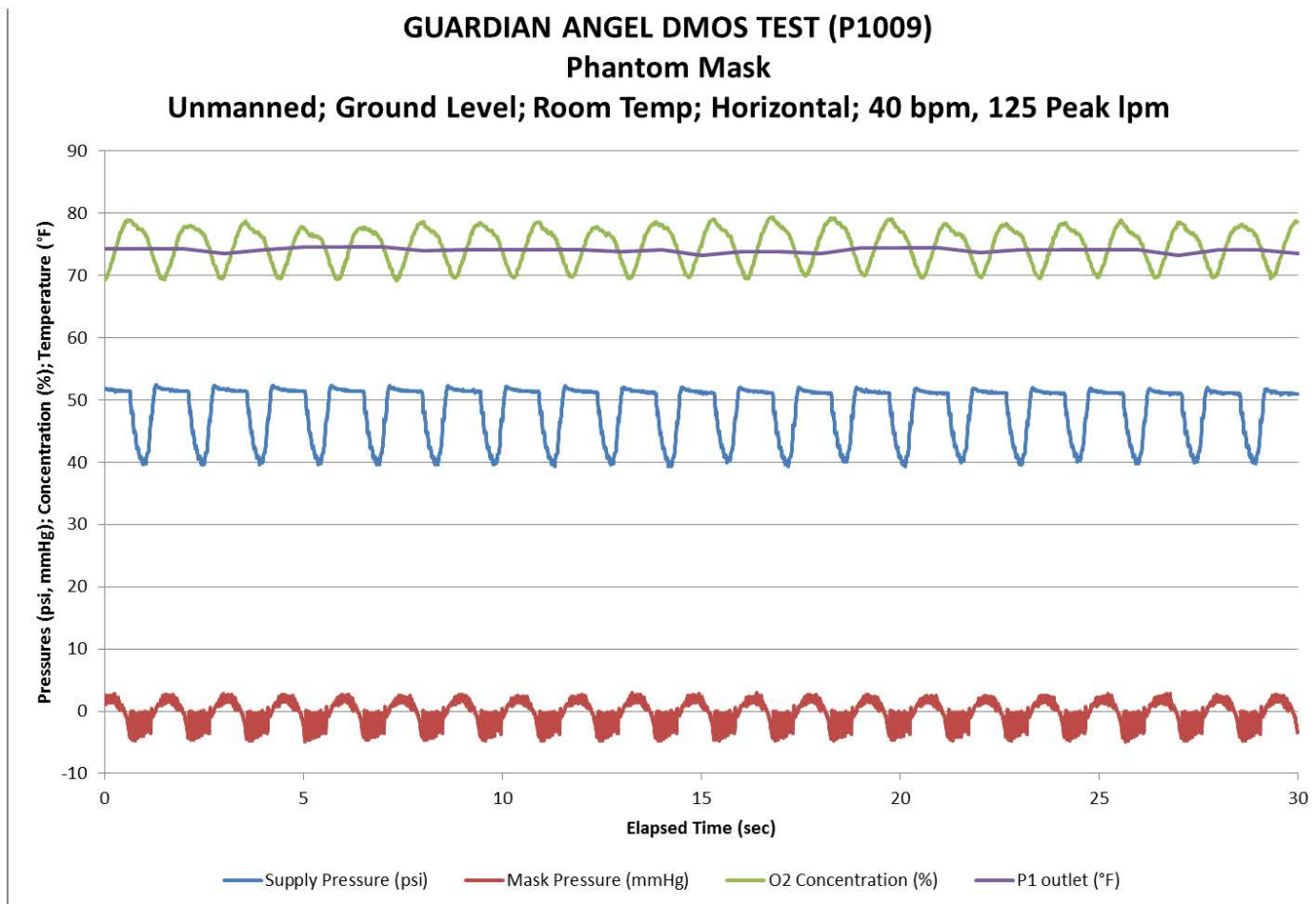


Figure D-90

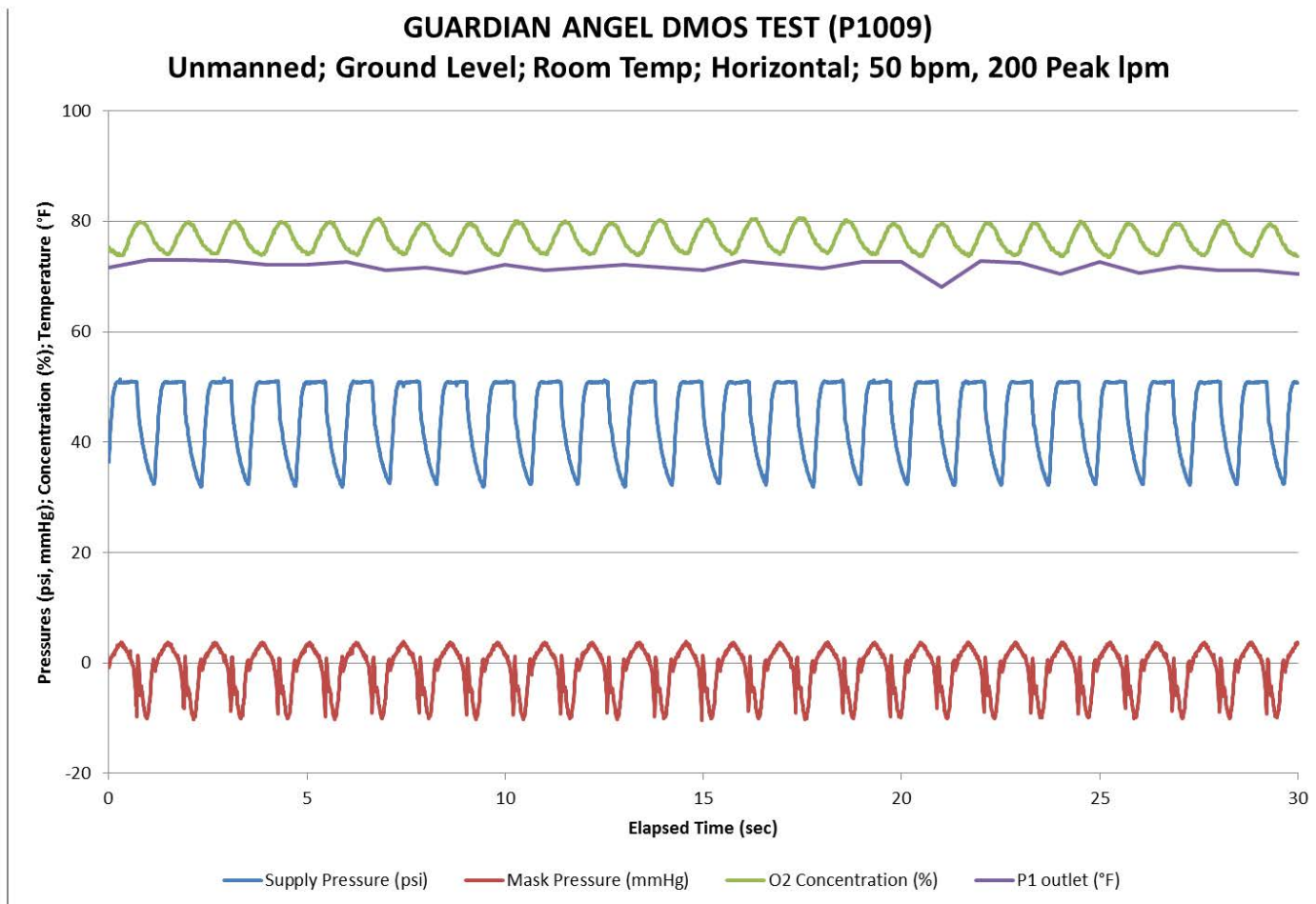


Figure D-91

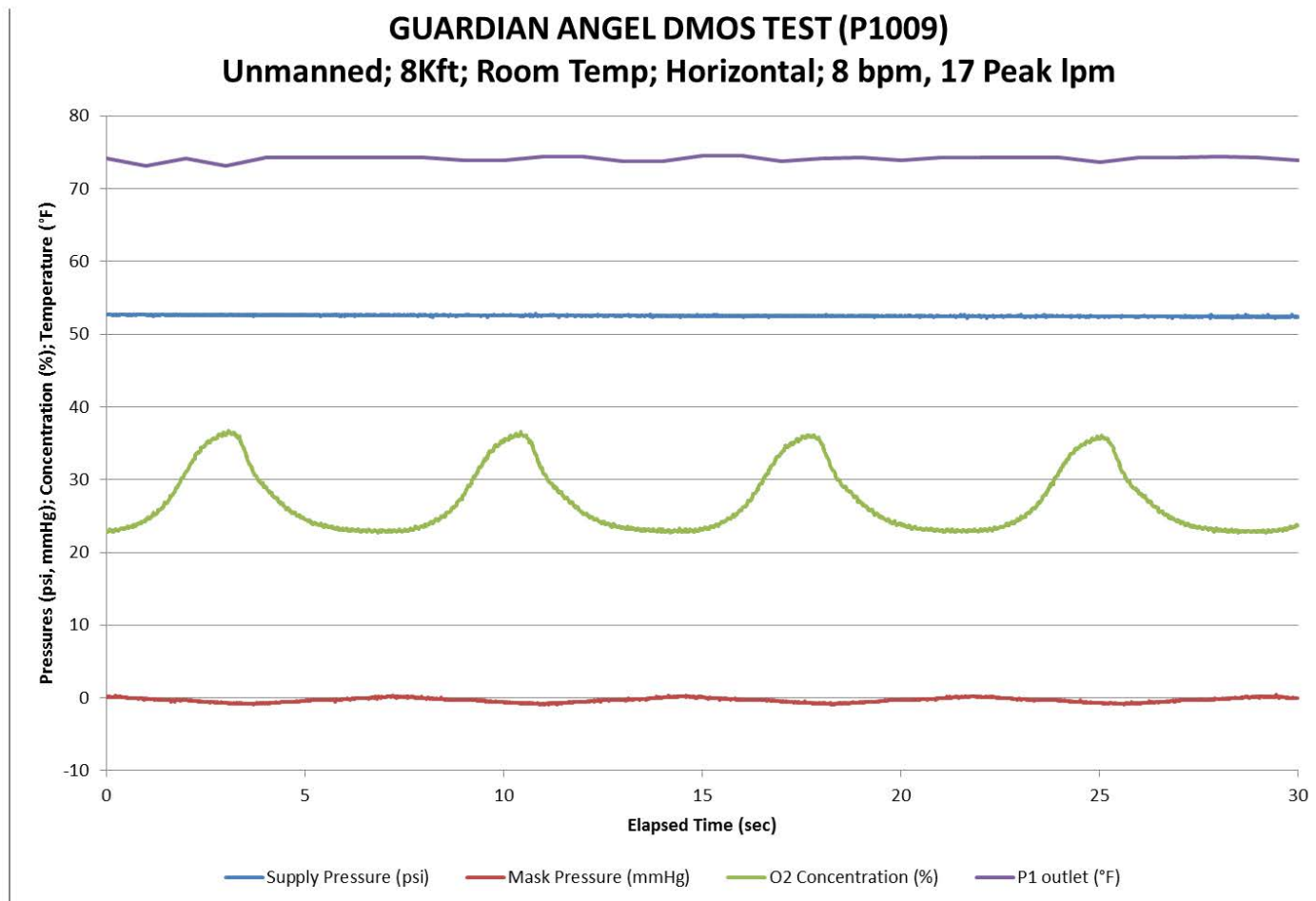


Figure D-92

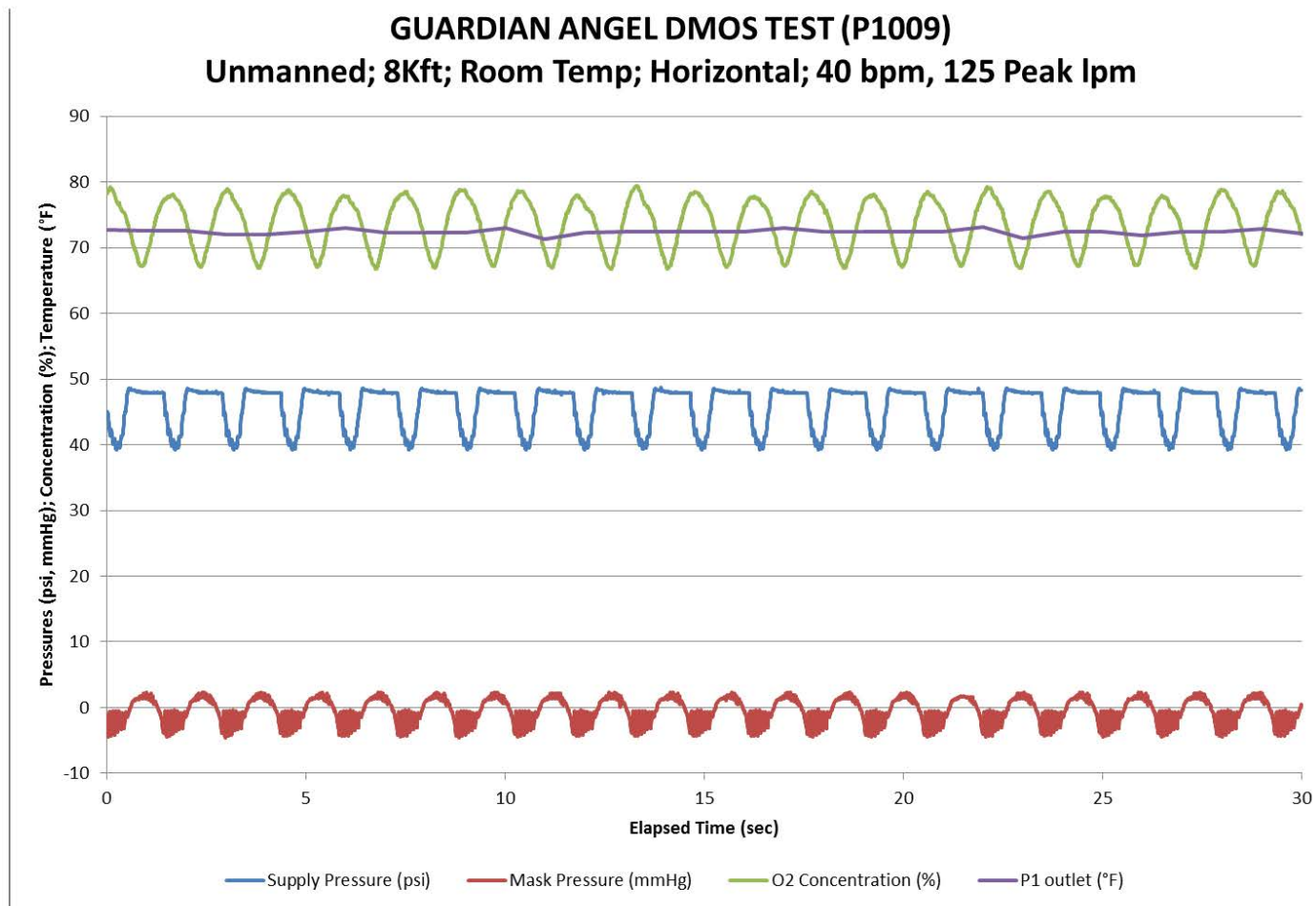


Figure D-93

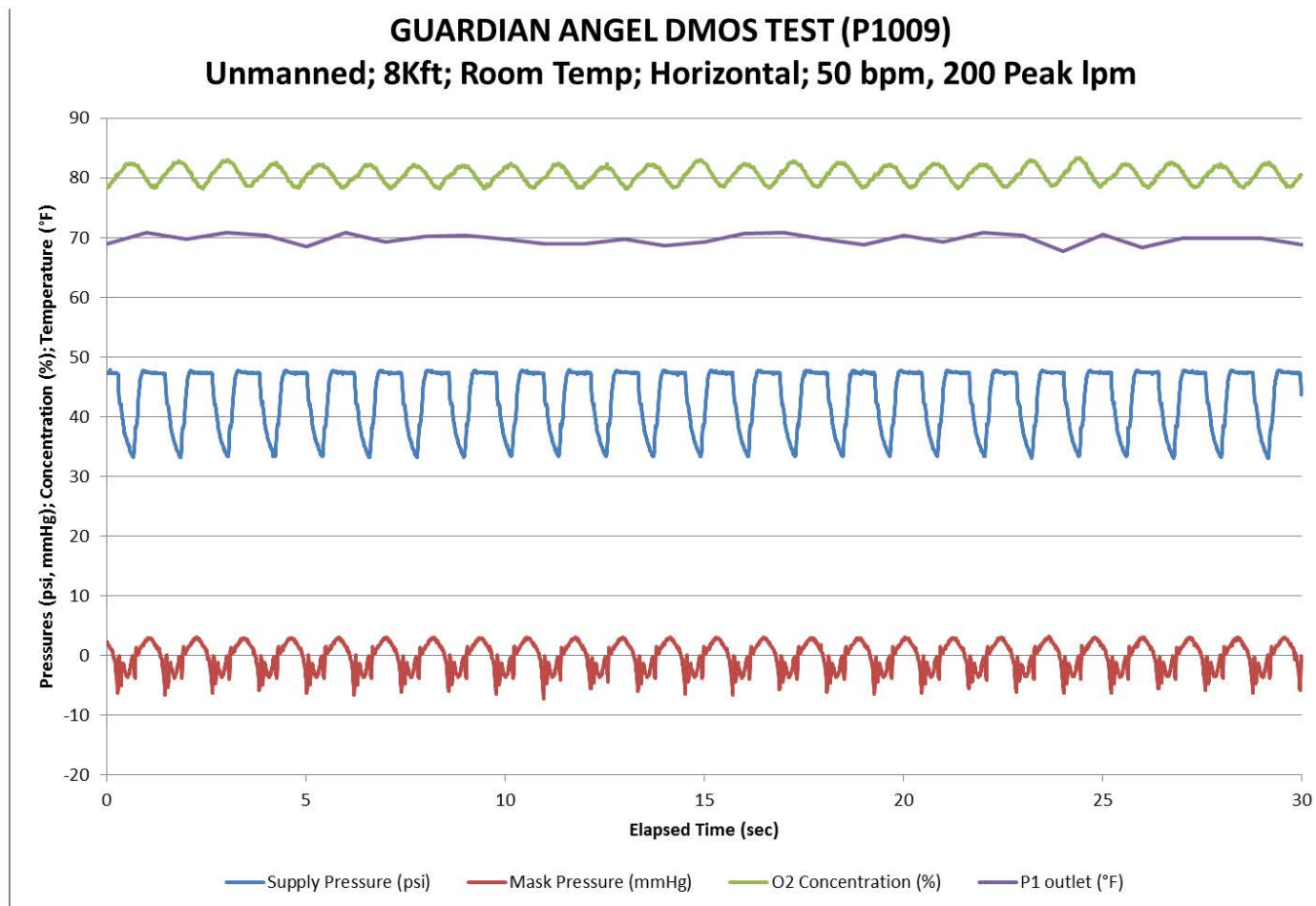


Figure D-94

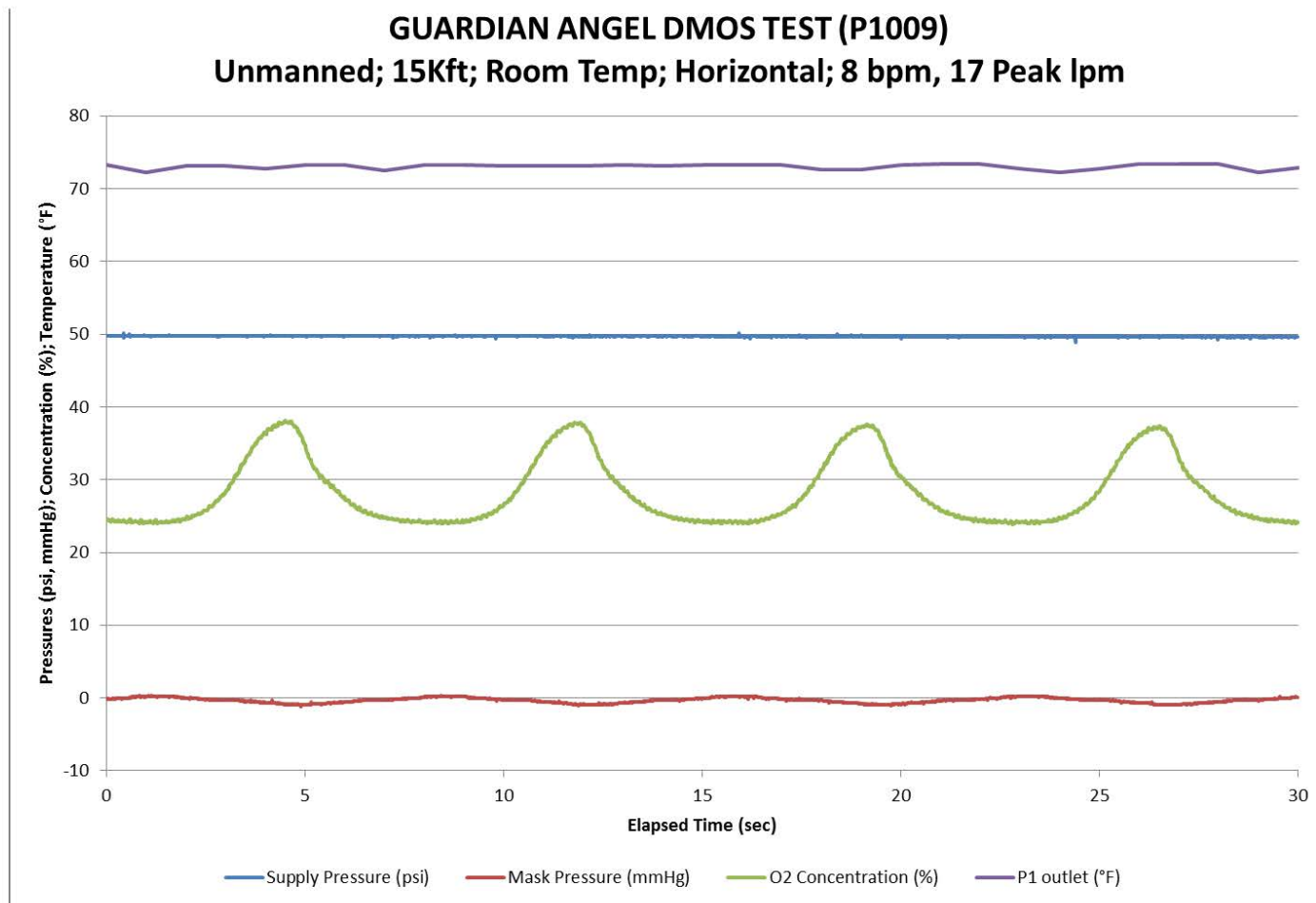


Figure D-95

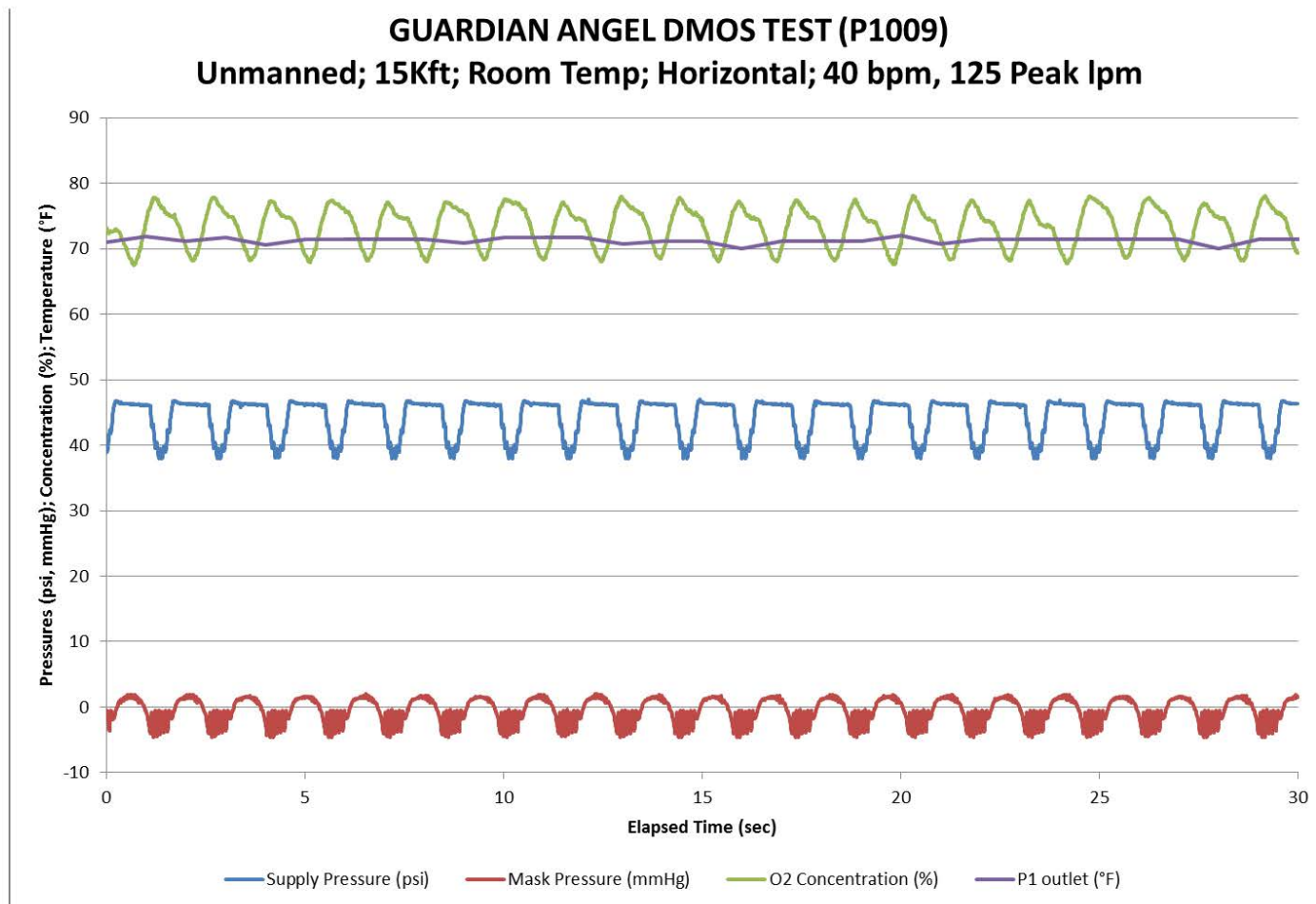


Figure D-96

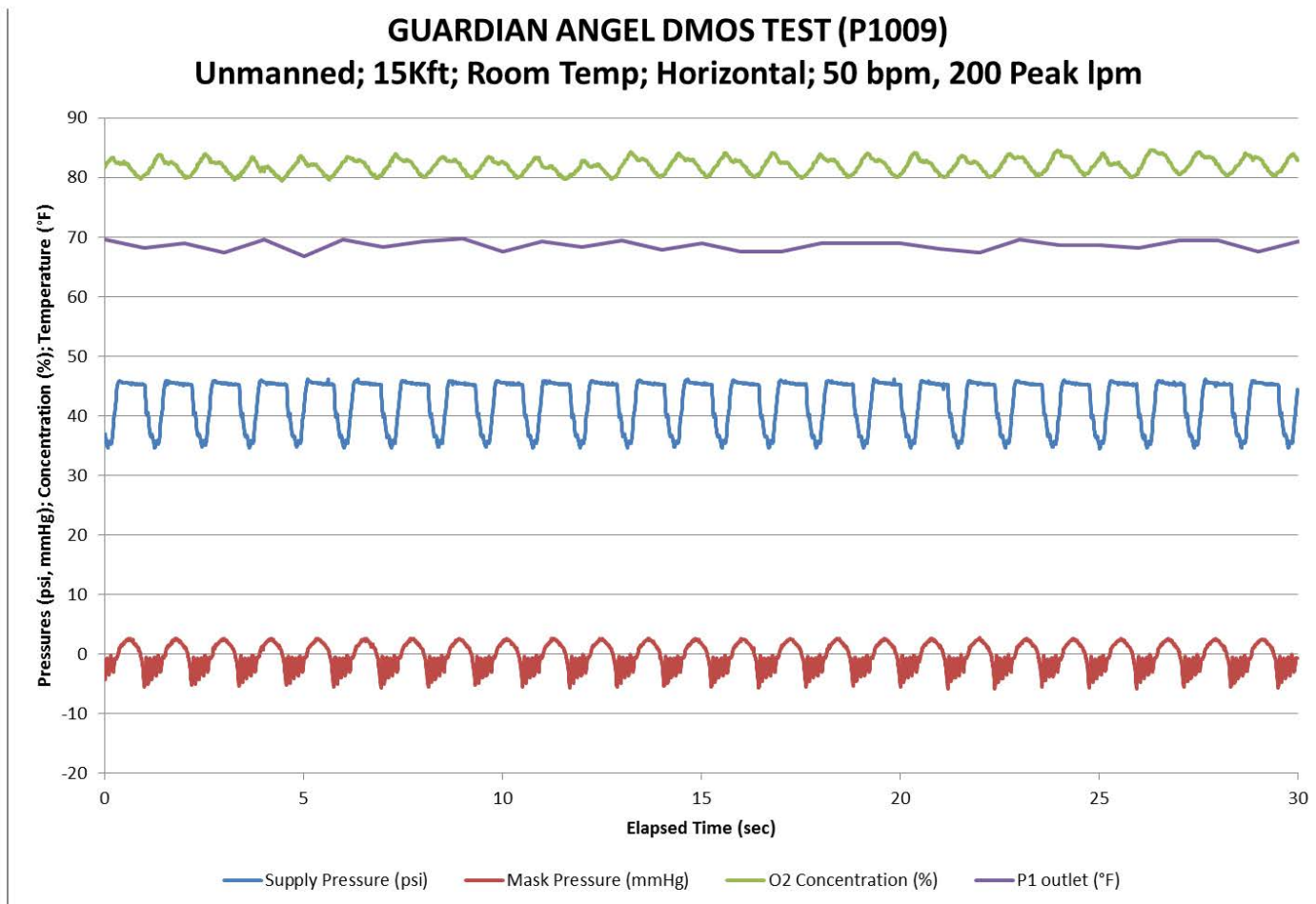


Figure D-97

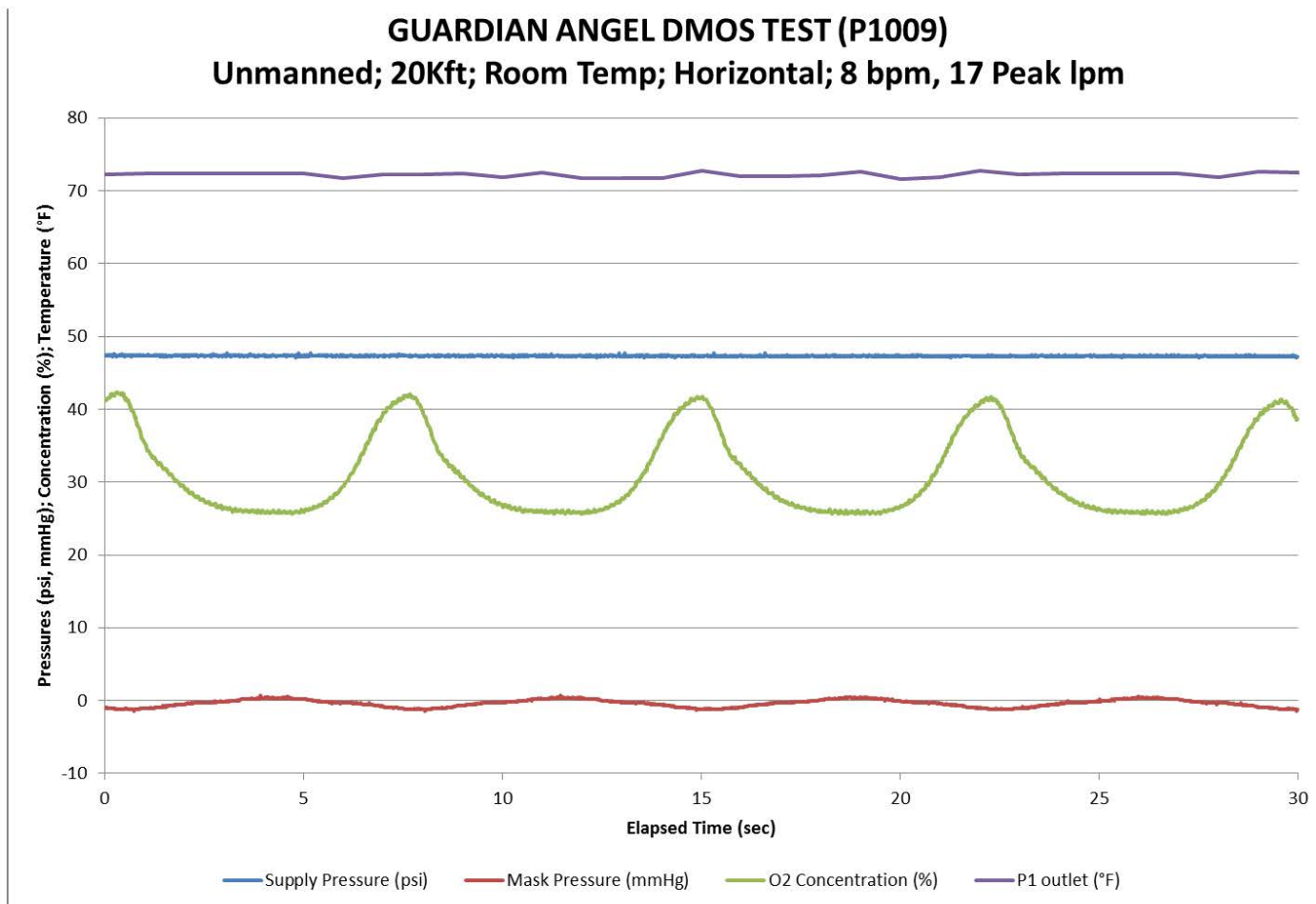


Figure D-98

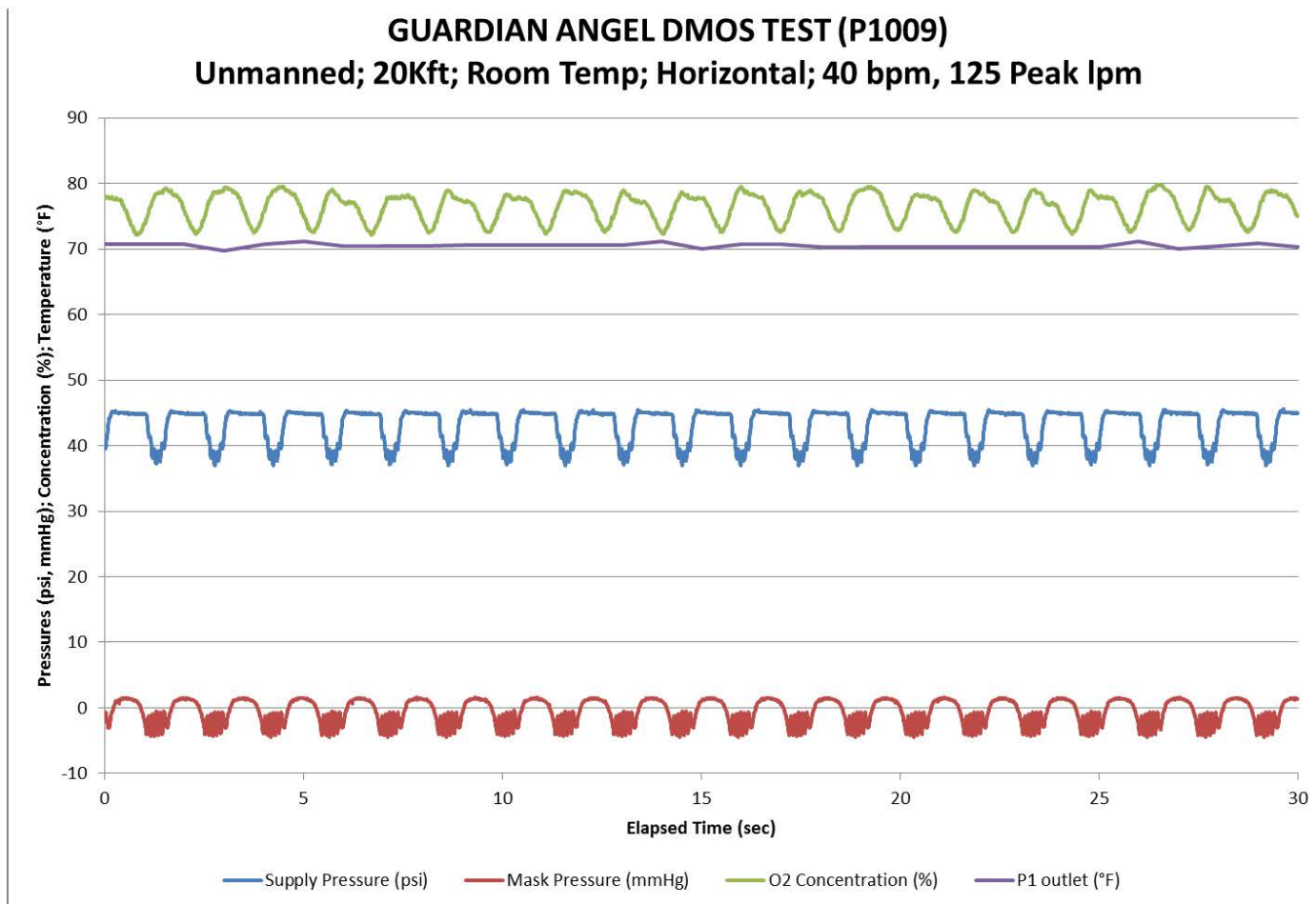


Figure D-99

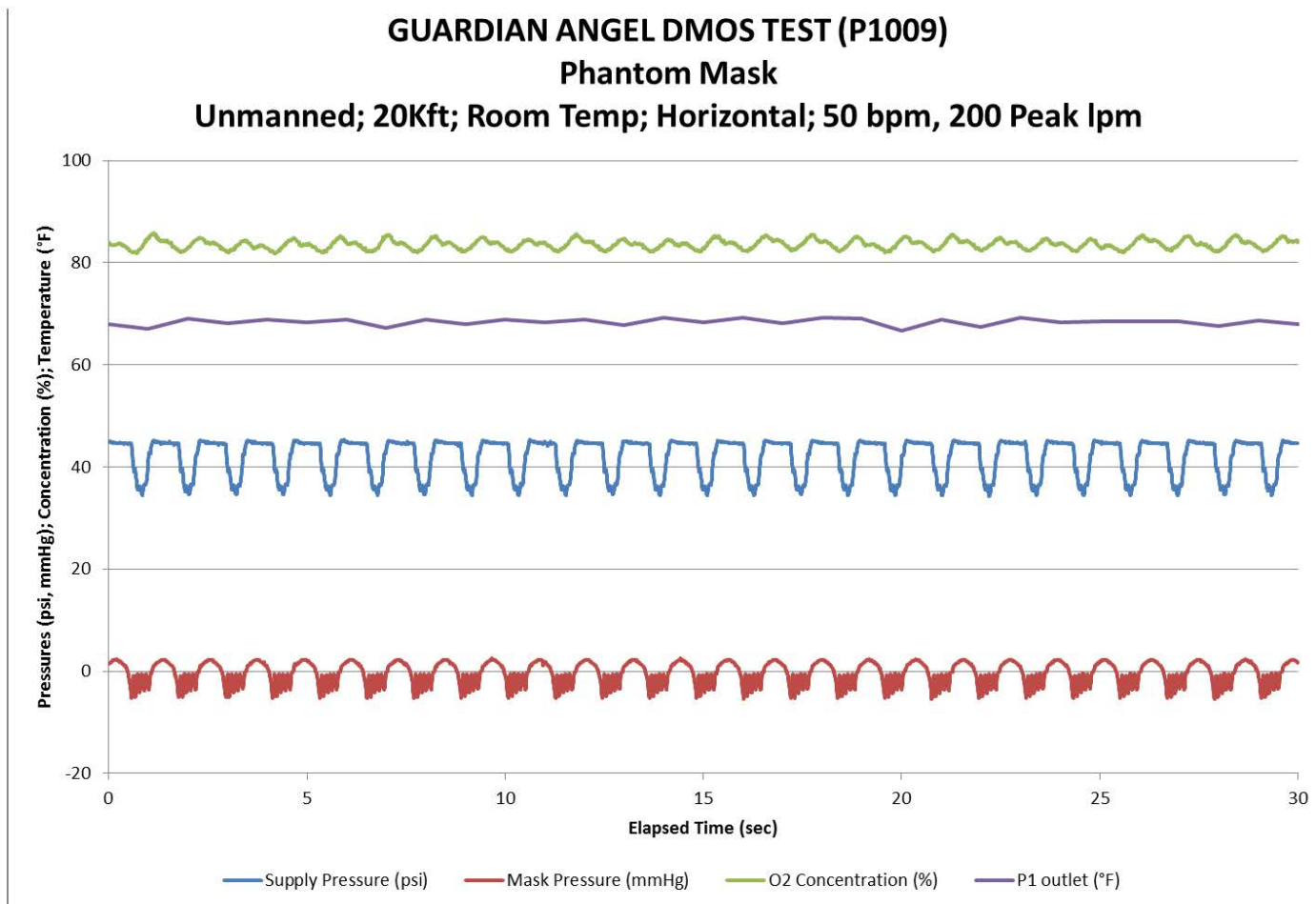


Figure D-100

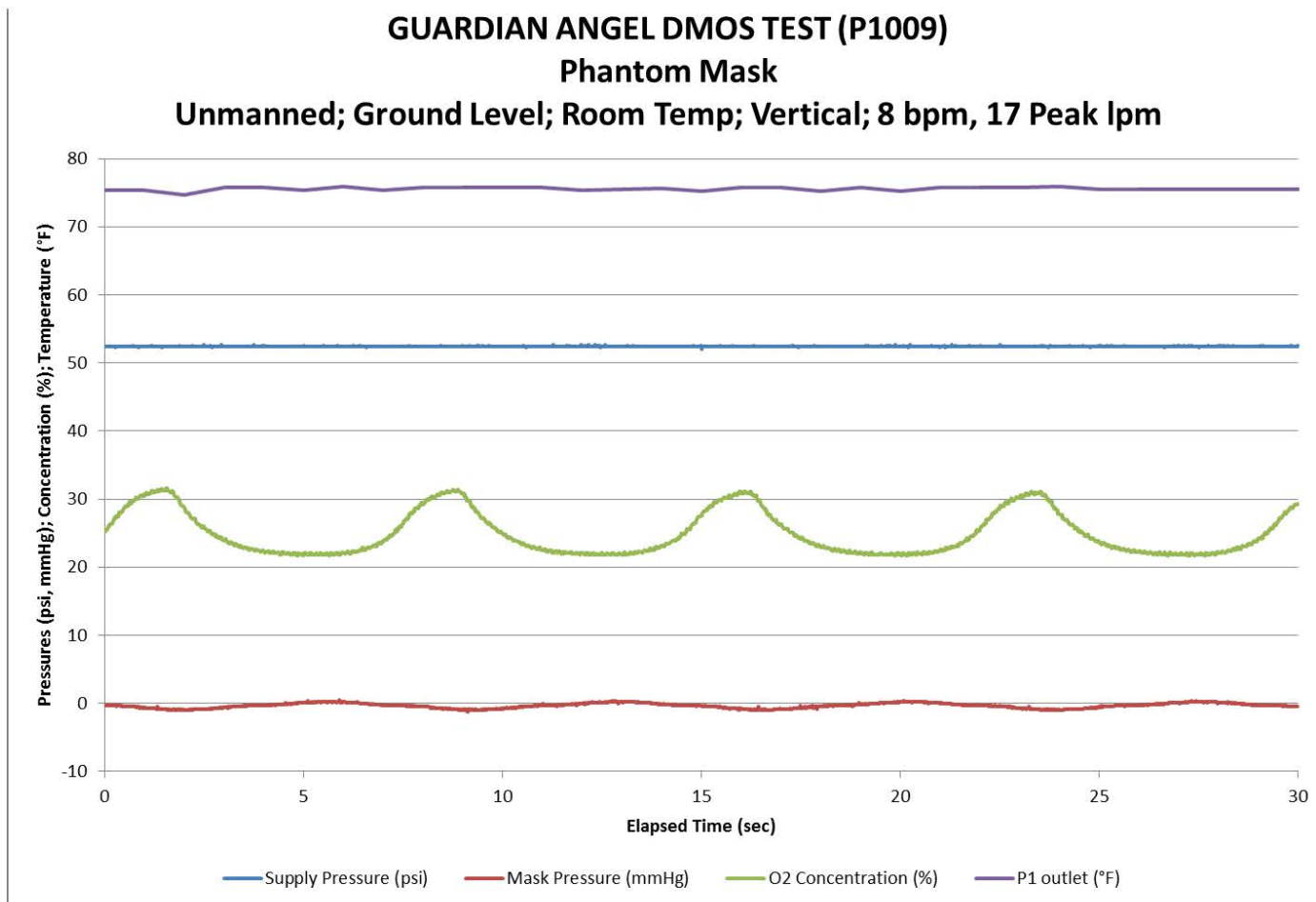


Figure D-101

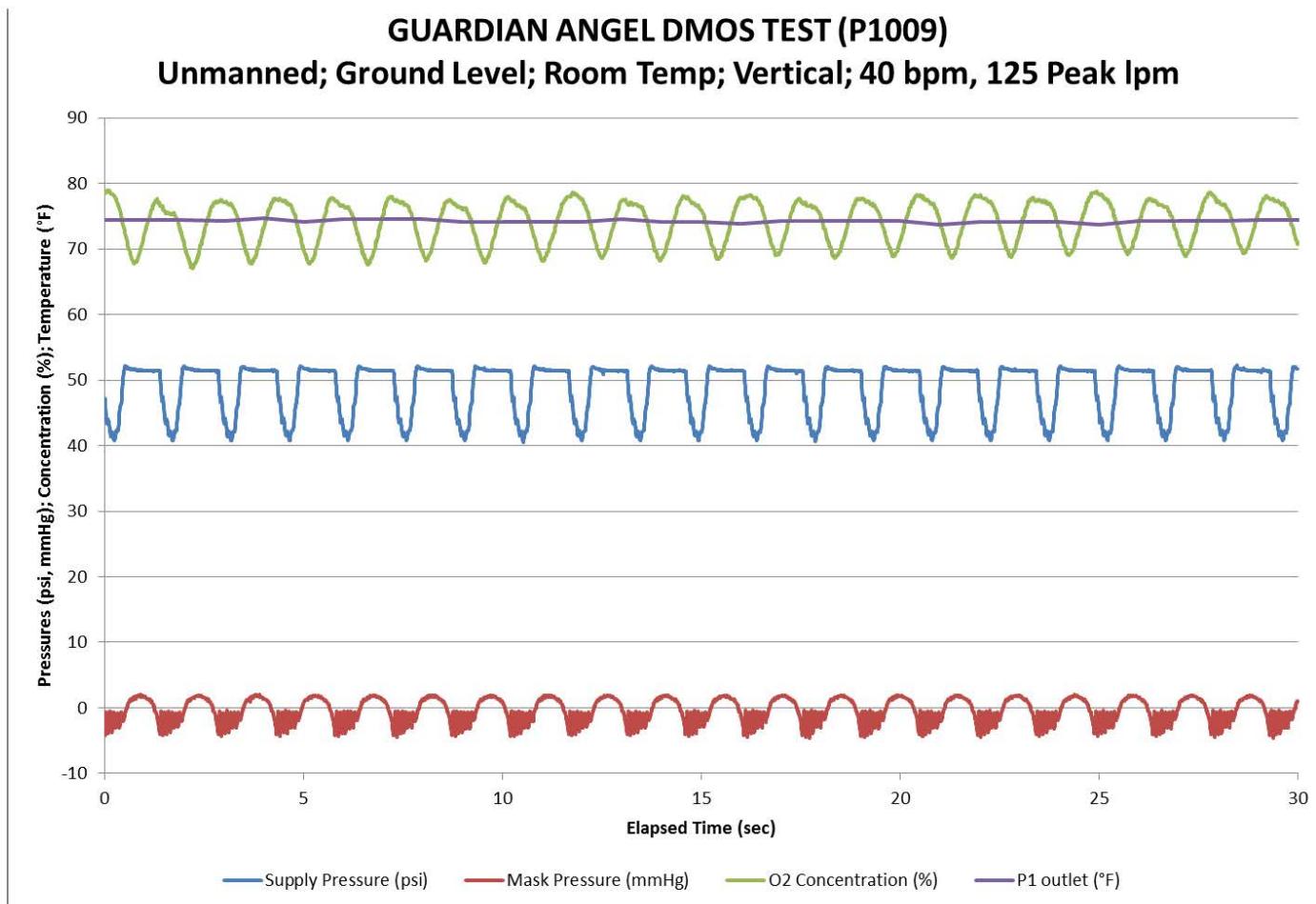


Figure D-102

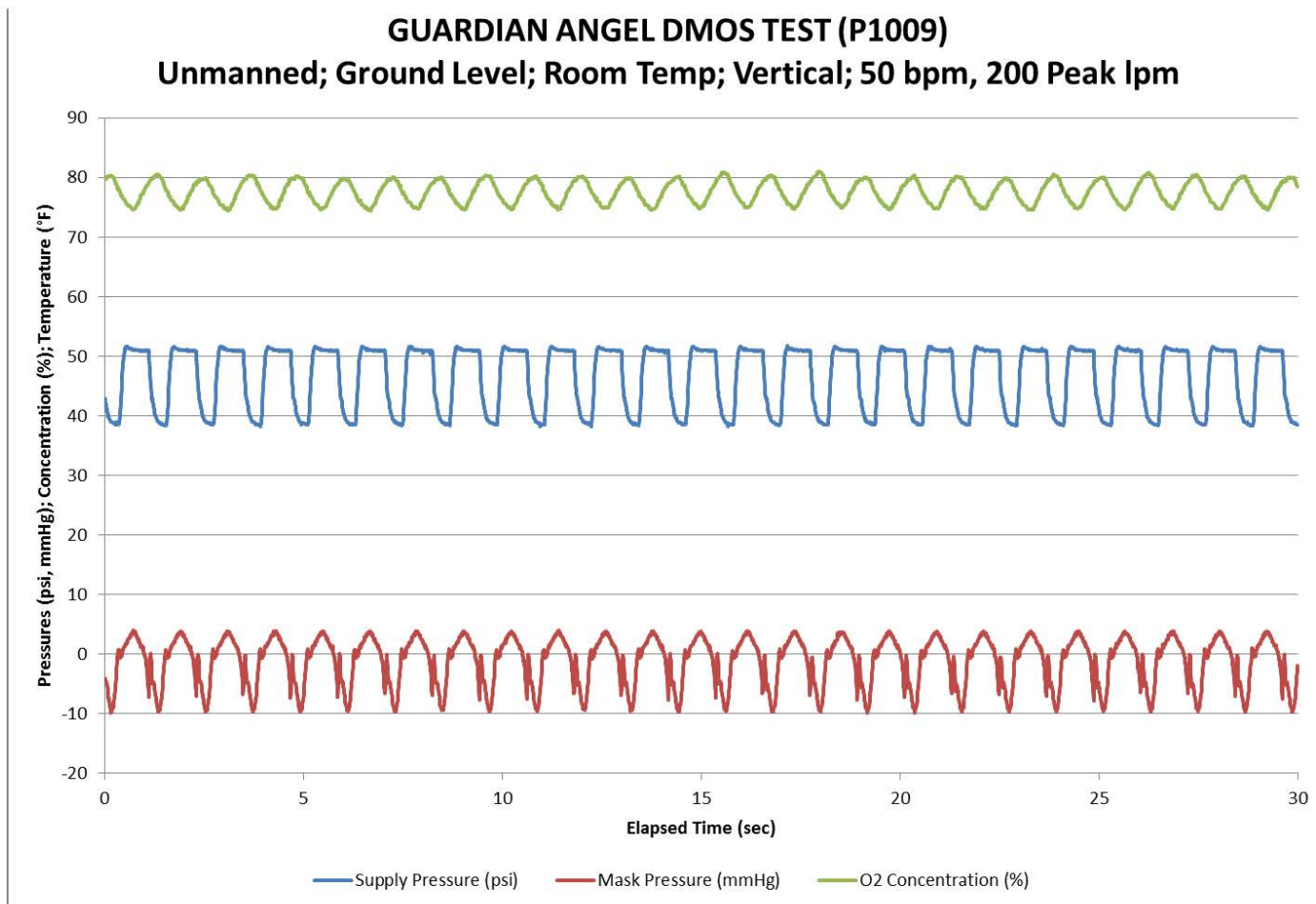


Figure D-103

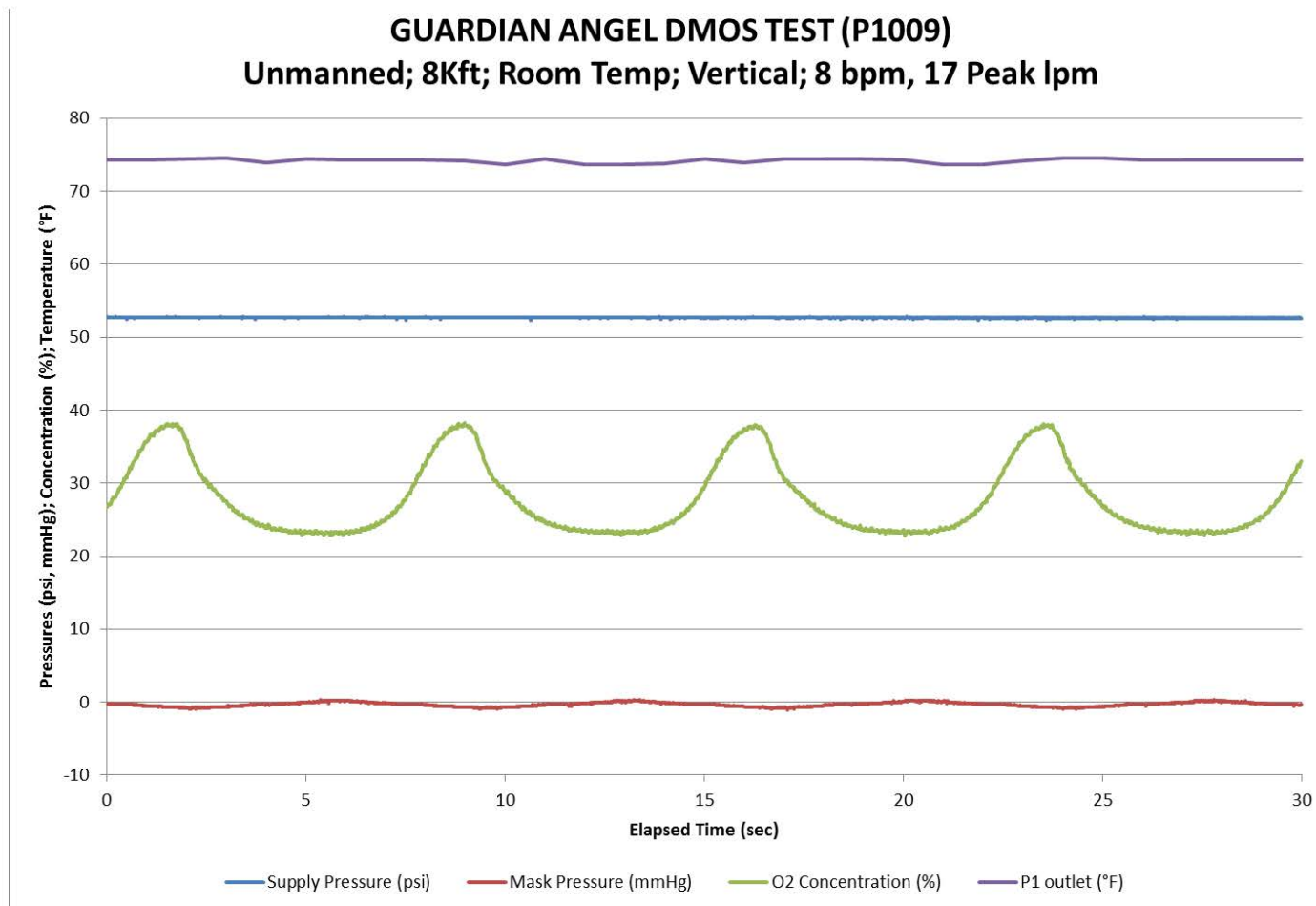


Figure D-104

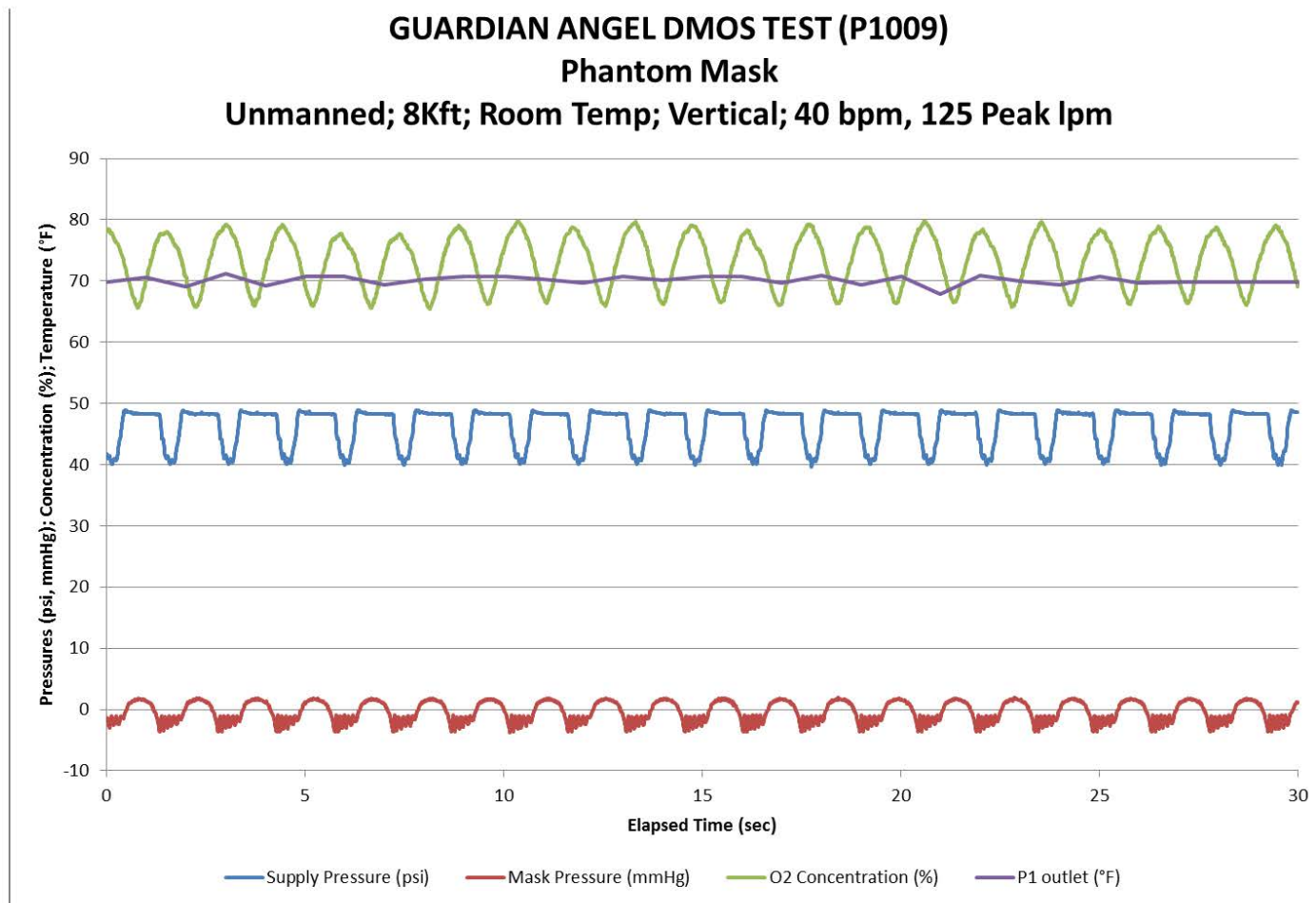


Figure D-105

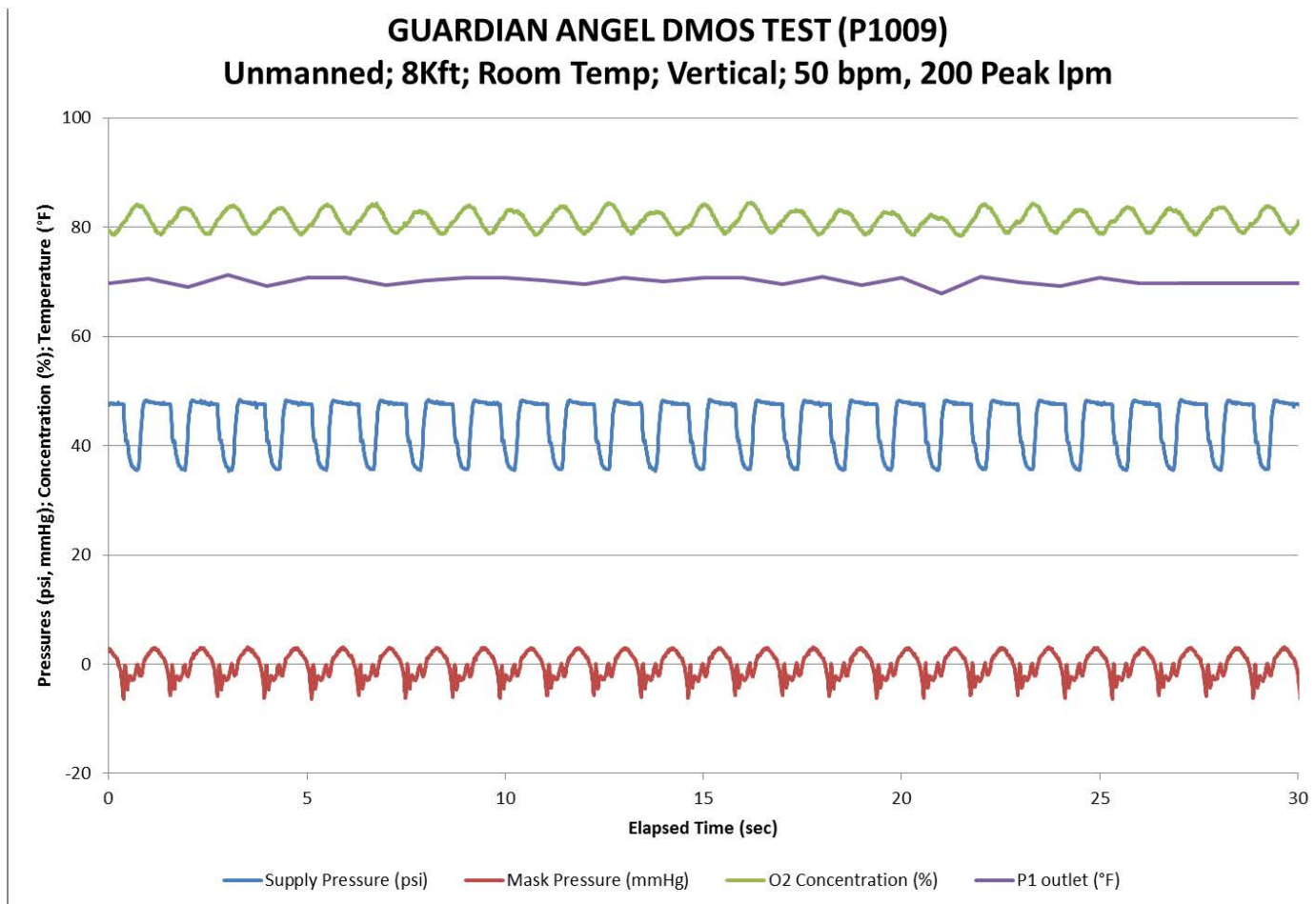


Figure D-106

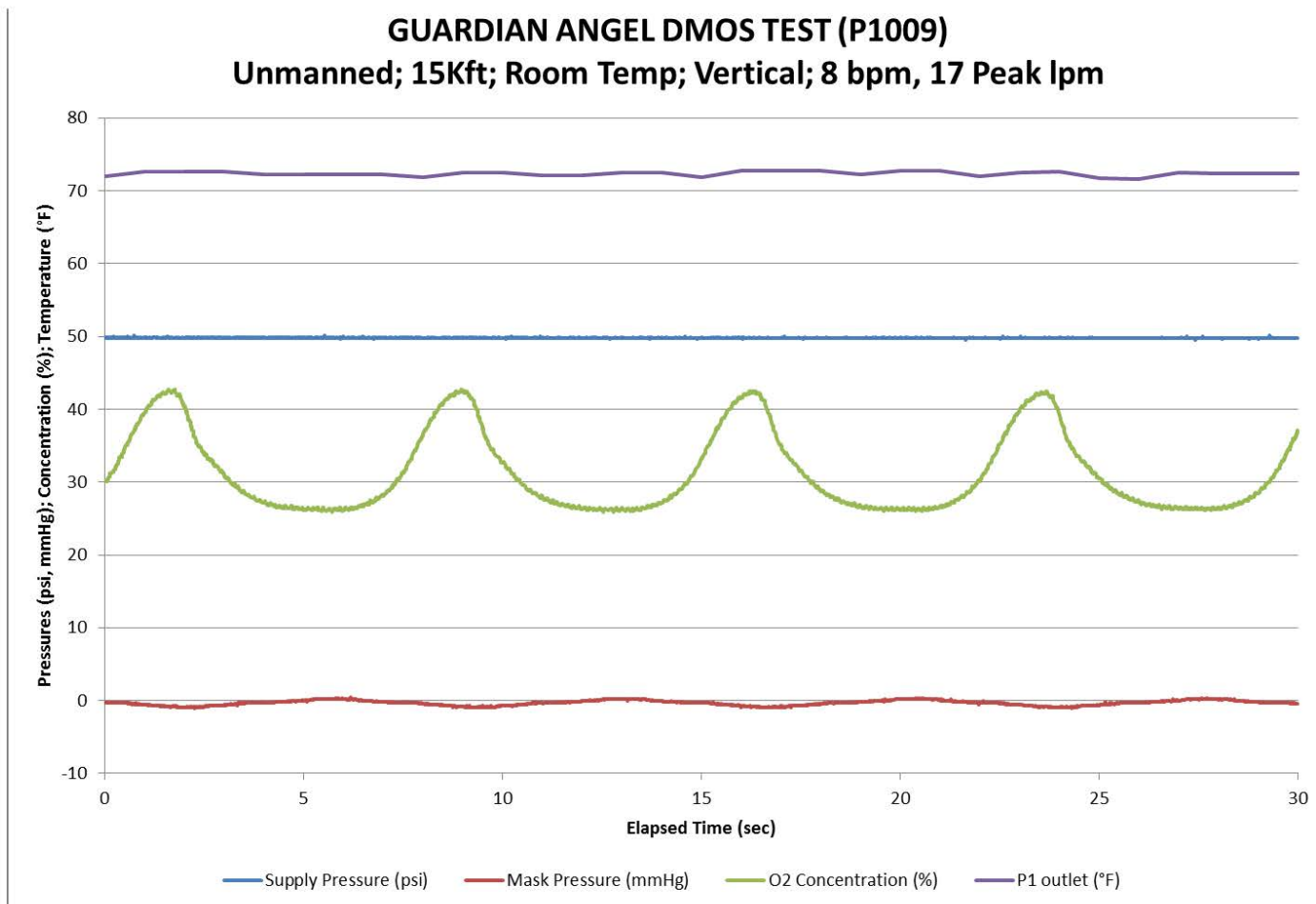


Figure D-107

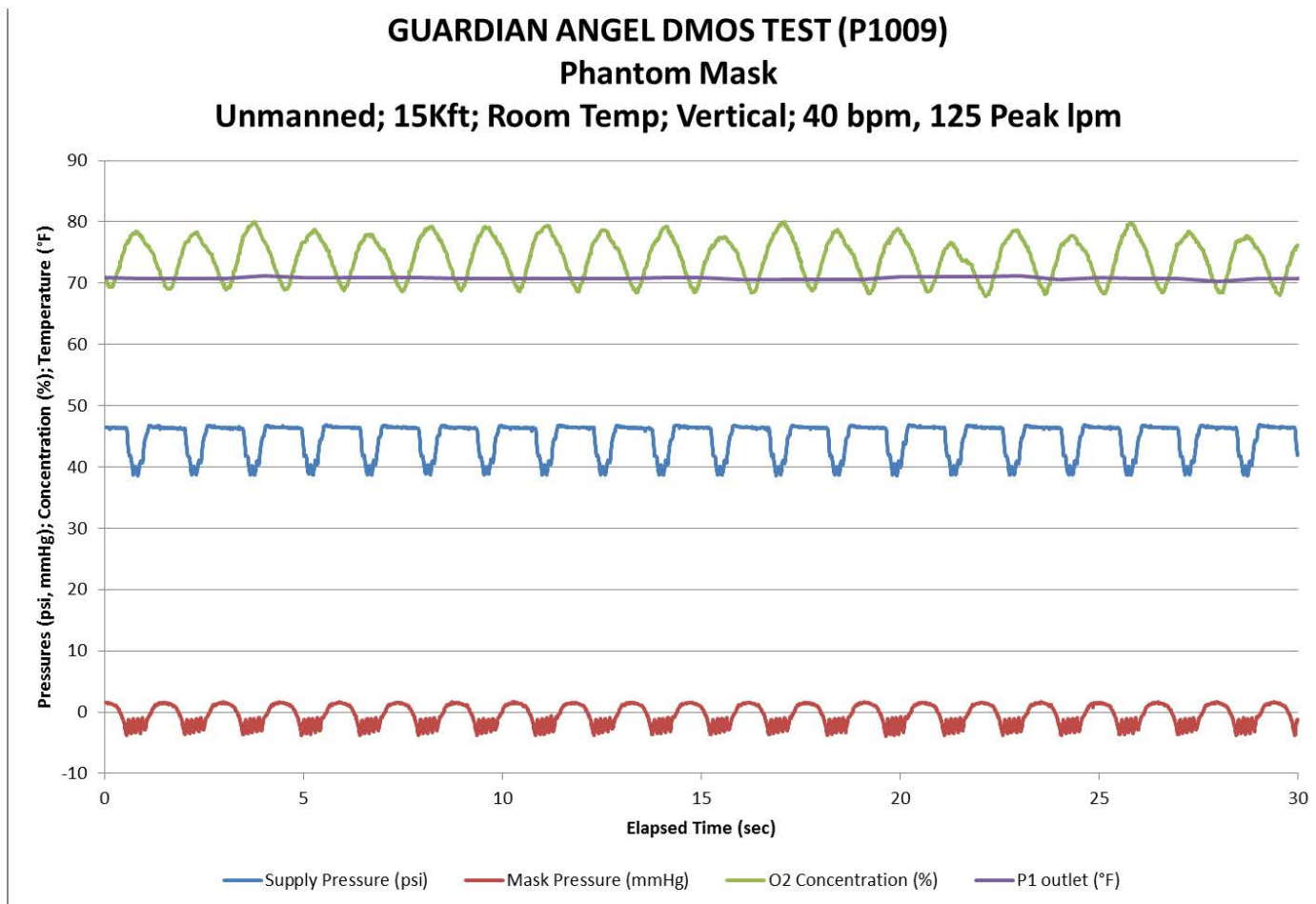


Figure D-108

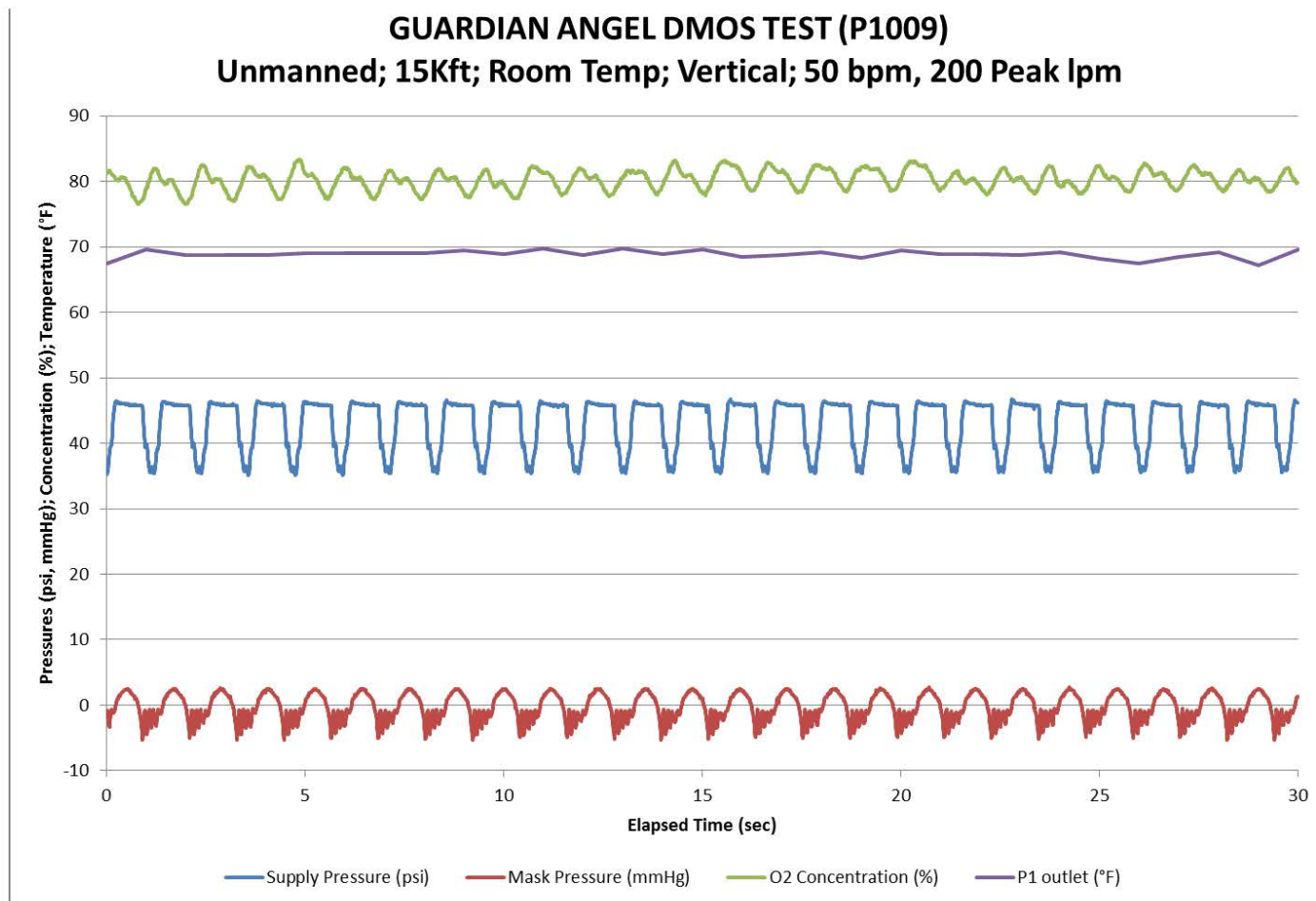


Figure D-109

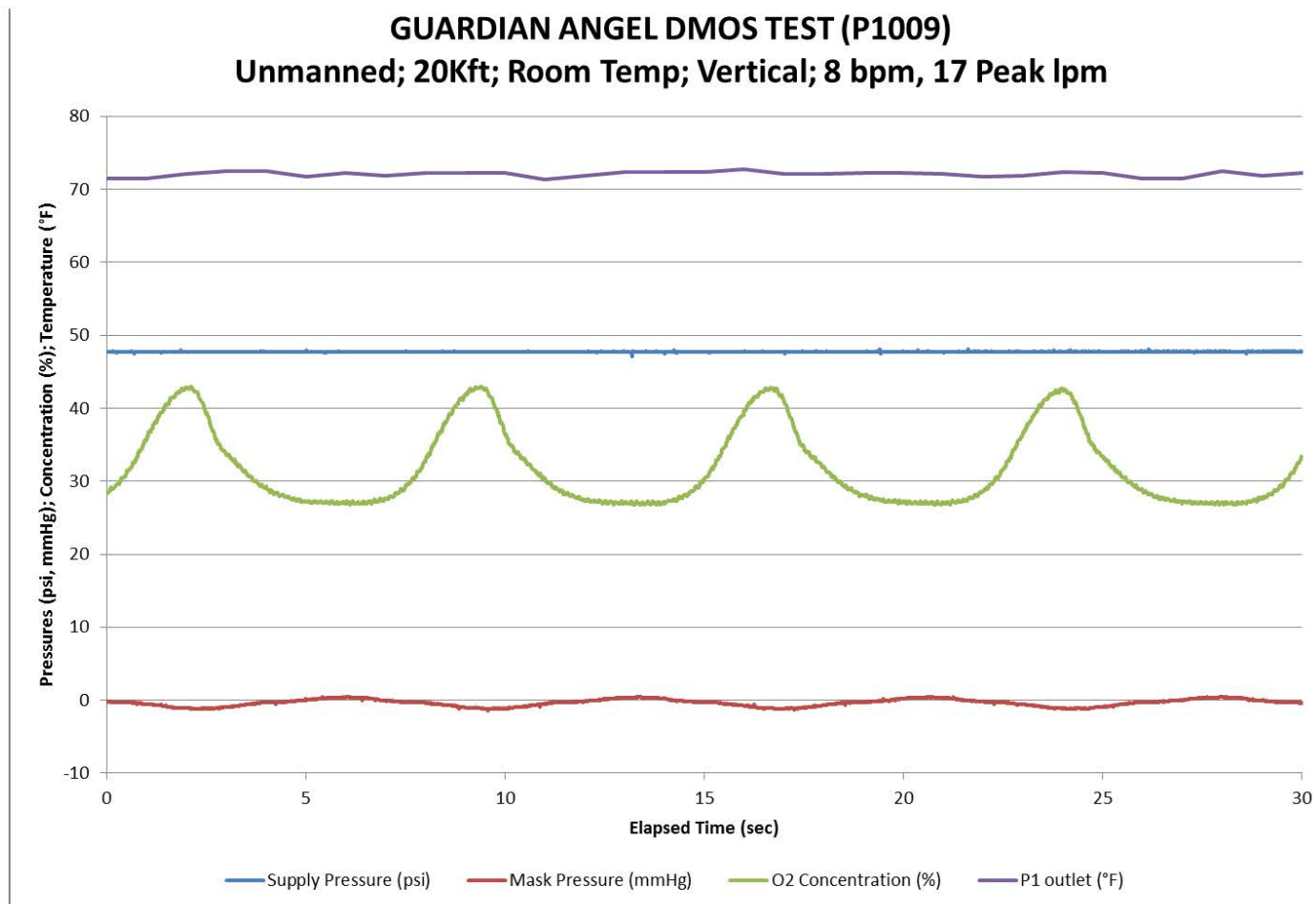


Figure D-110

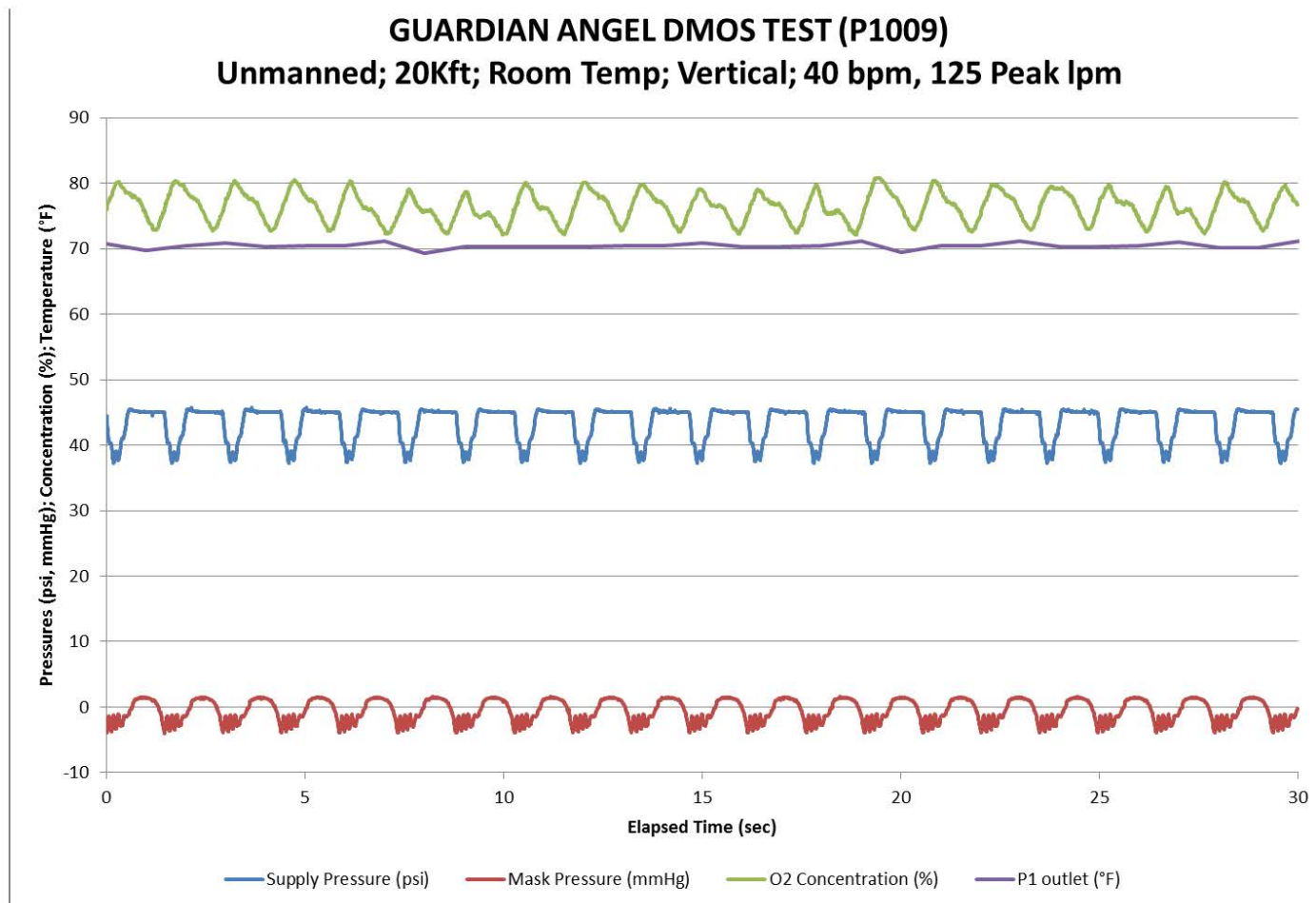


Figure D-111

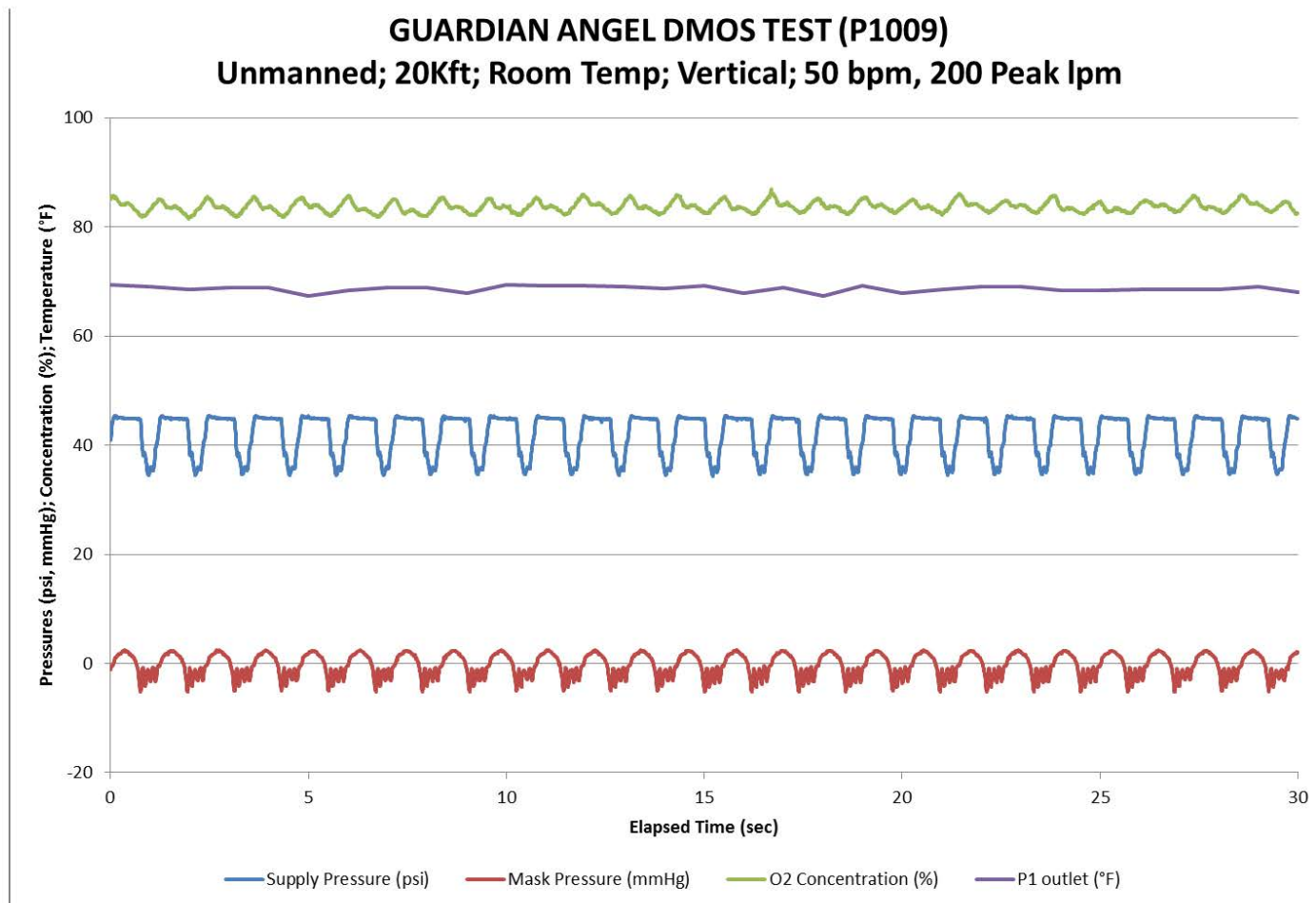


Figure D-112

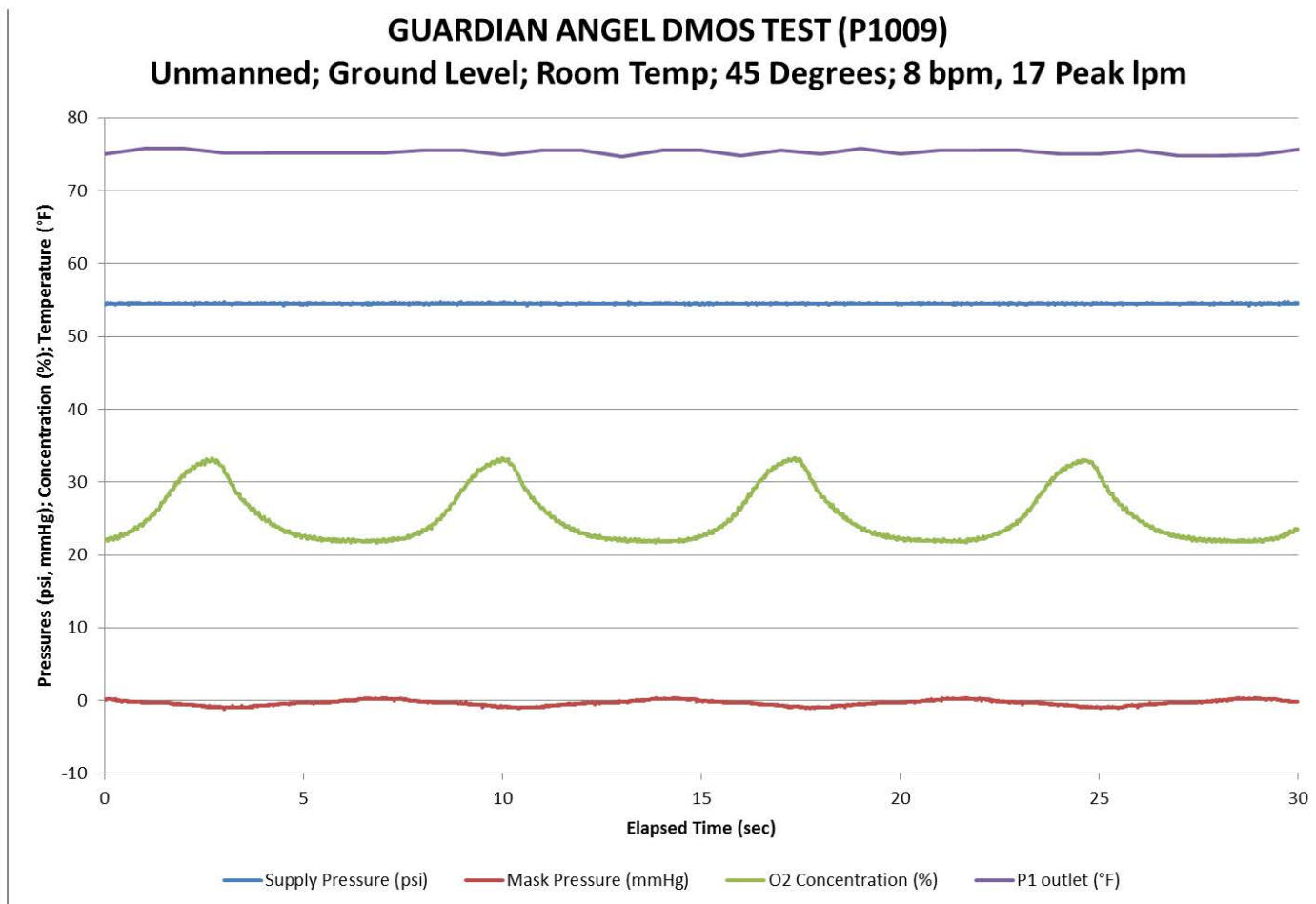


Figure D-113

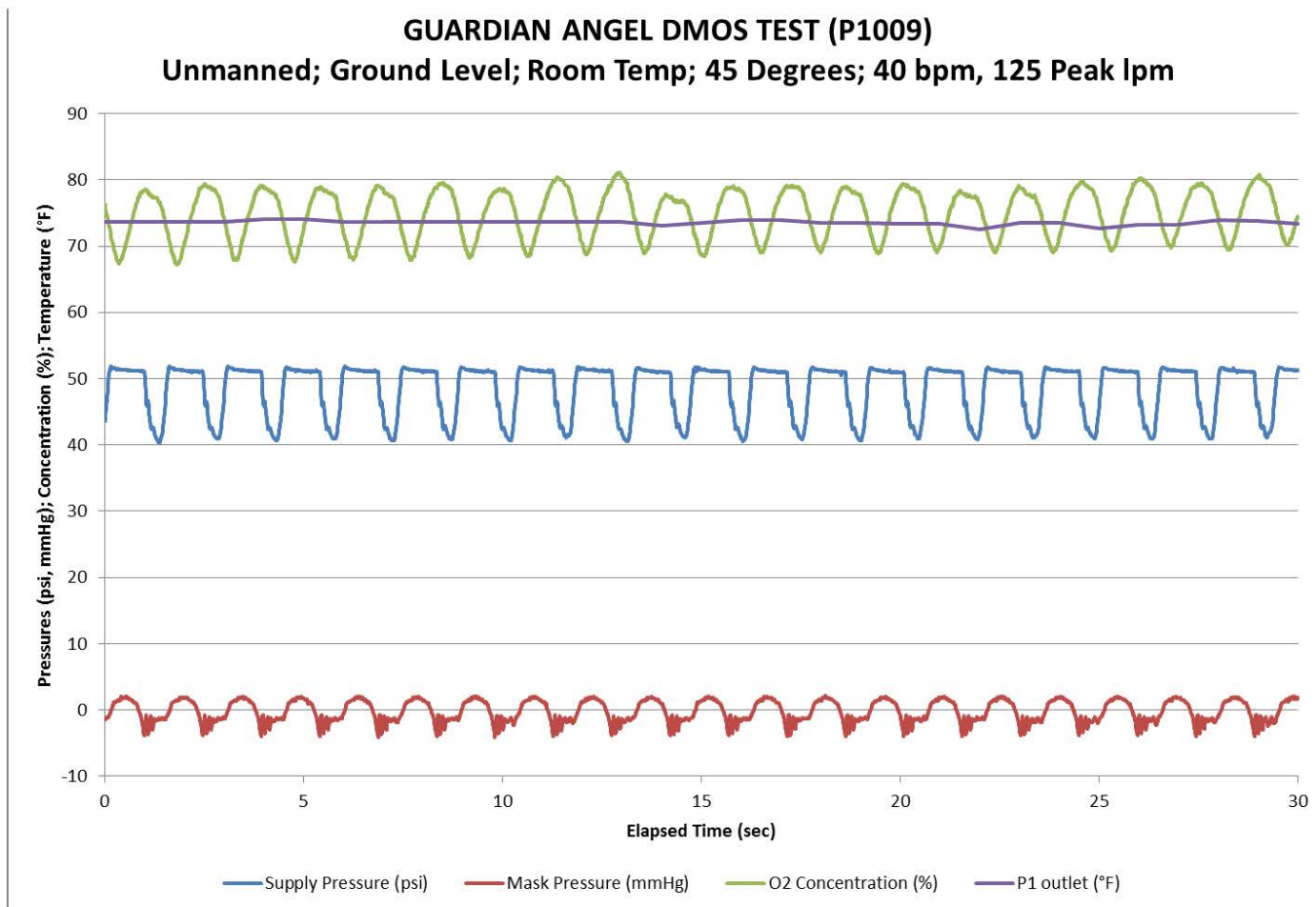


Figure D-114

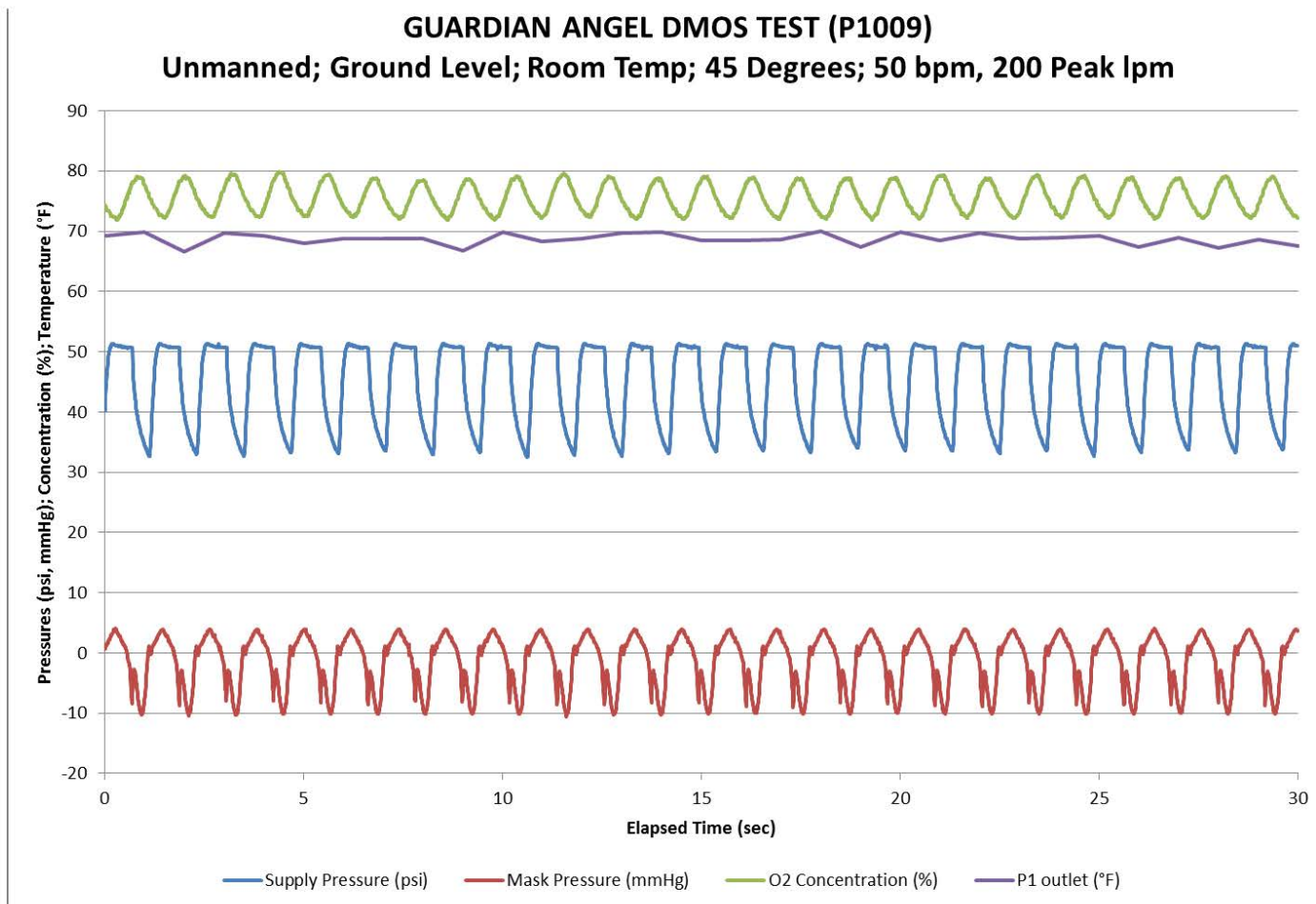


Figure D-115

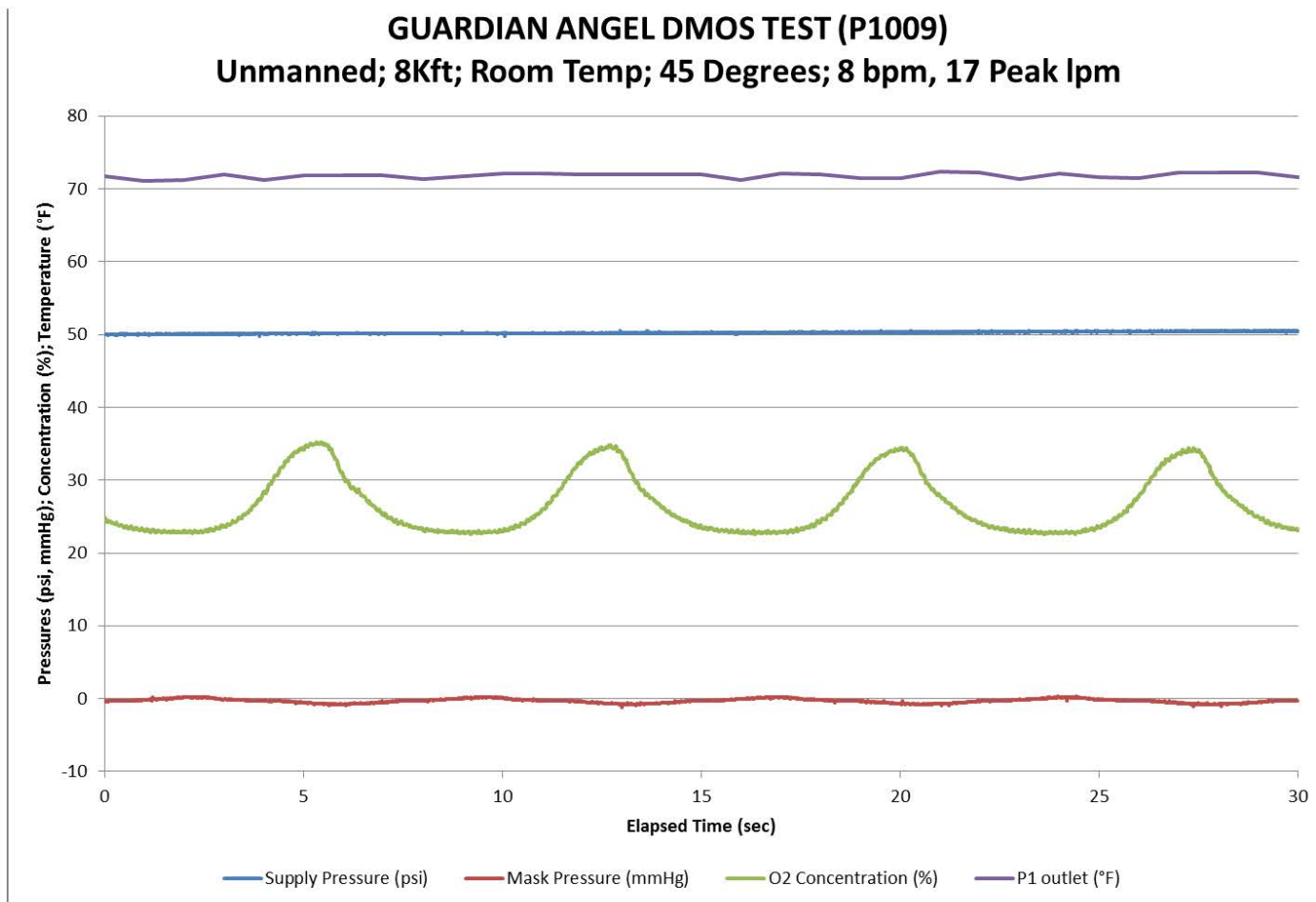


Figure D-116

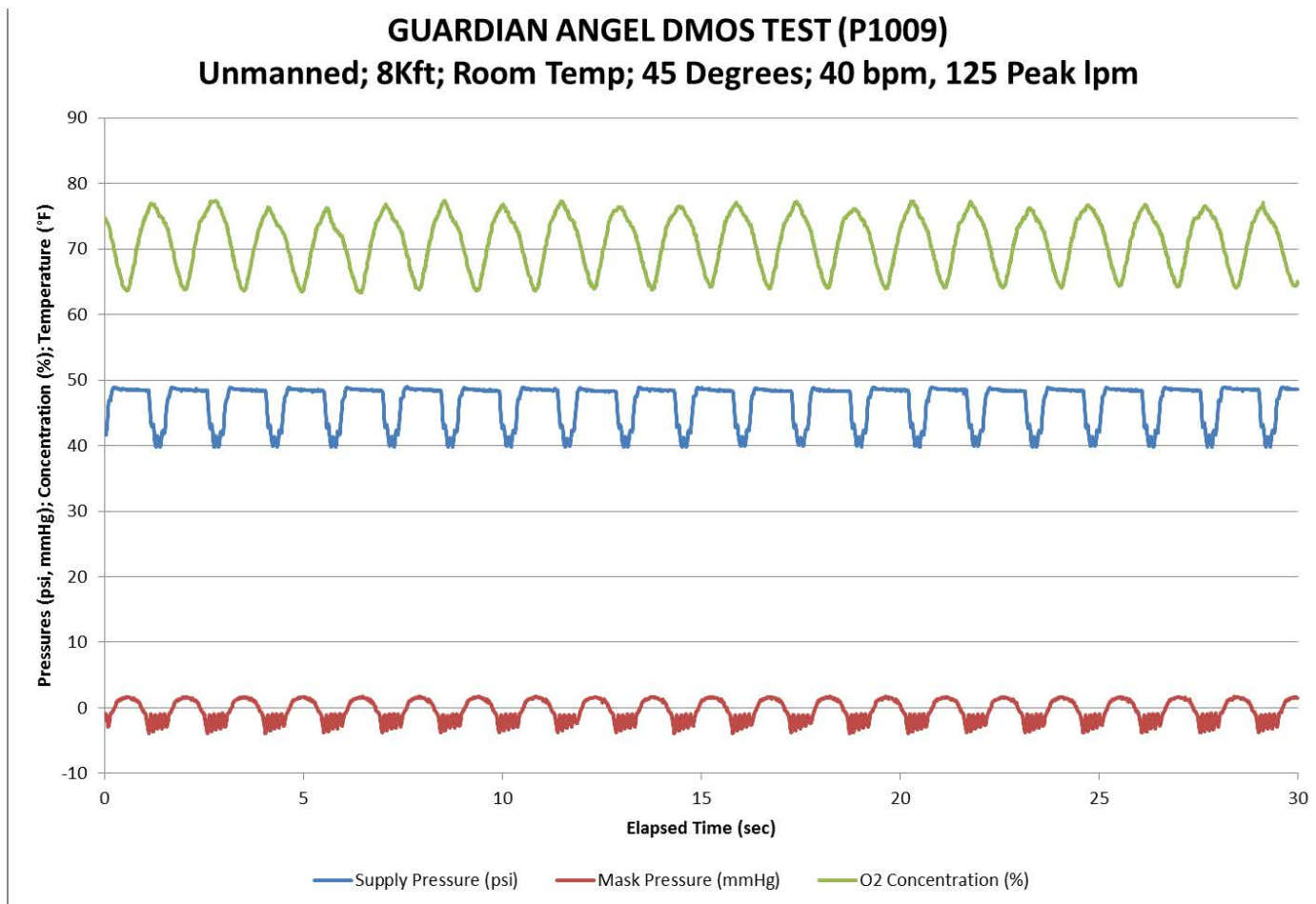


Figure D-117

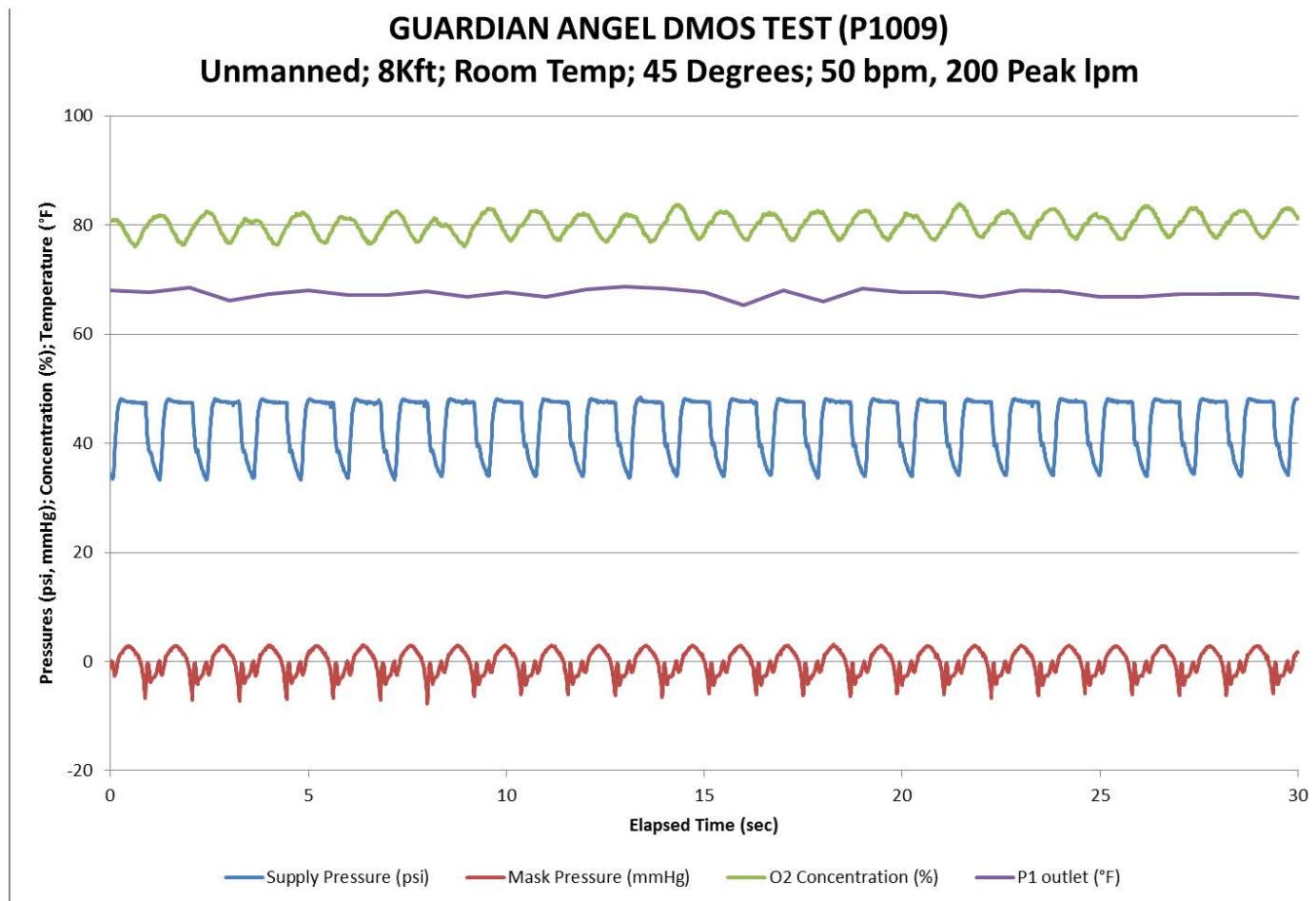


Figure D-118

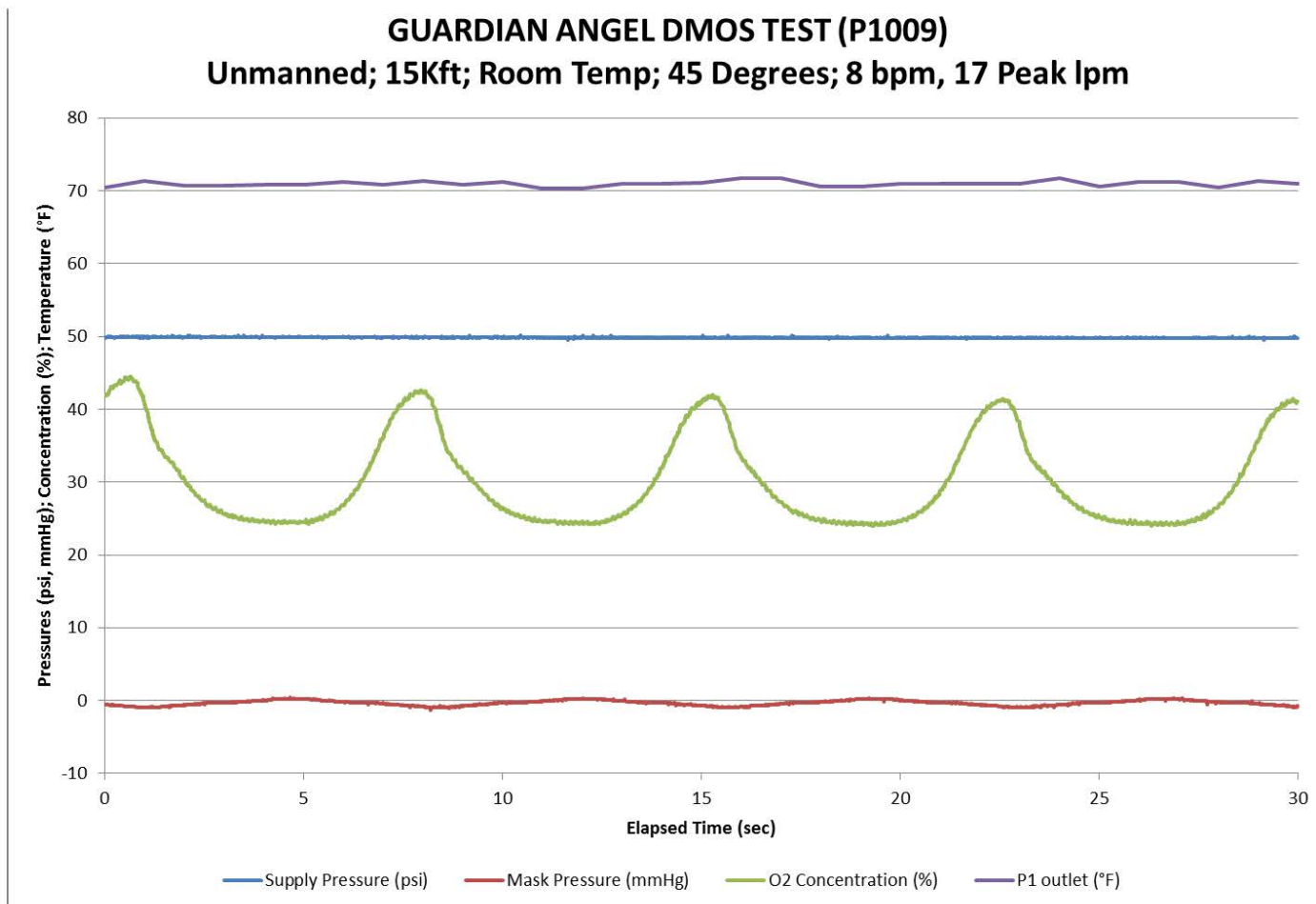


Figure D-119

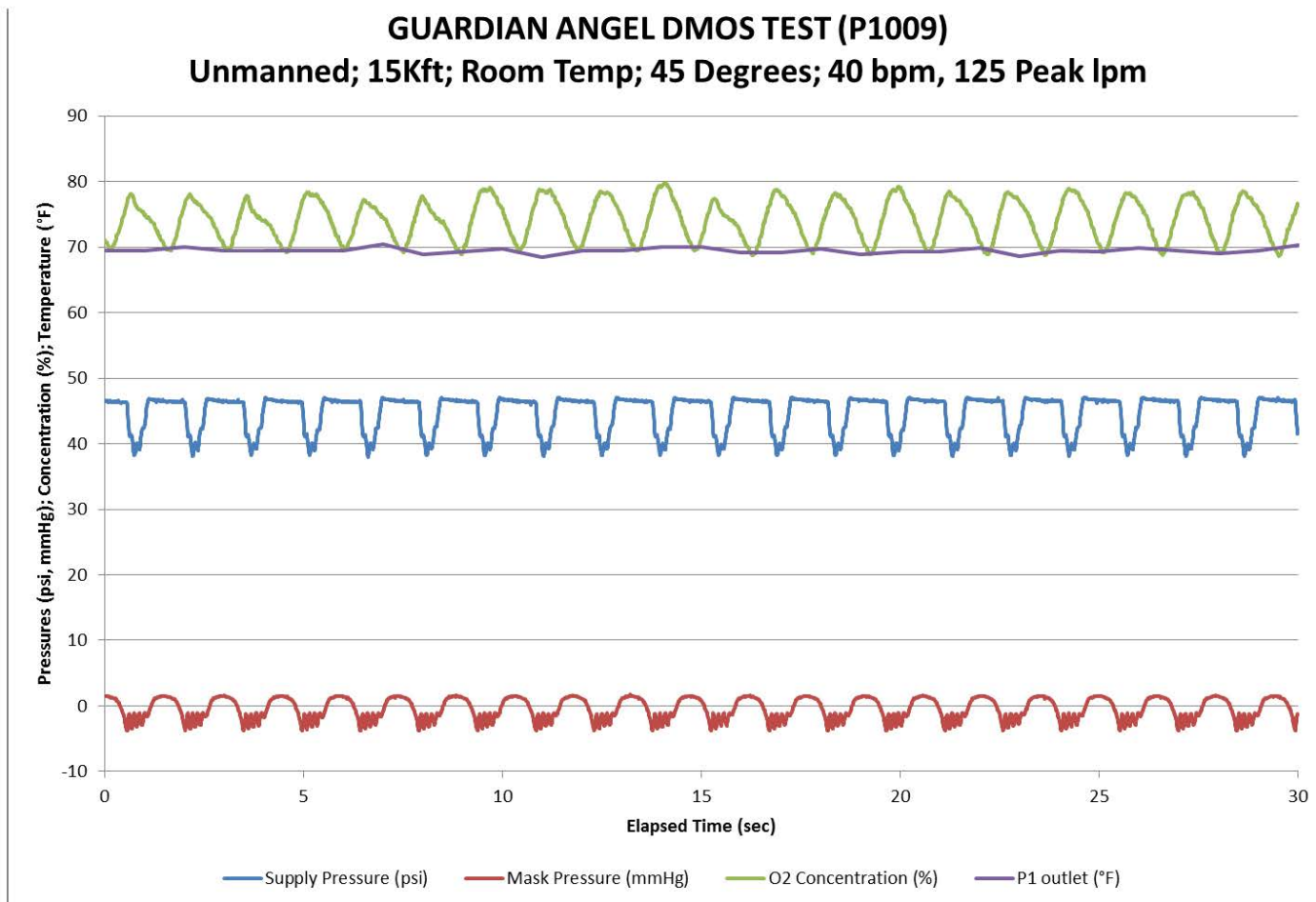


Figure D-120

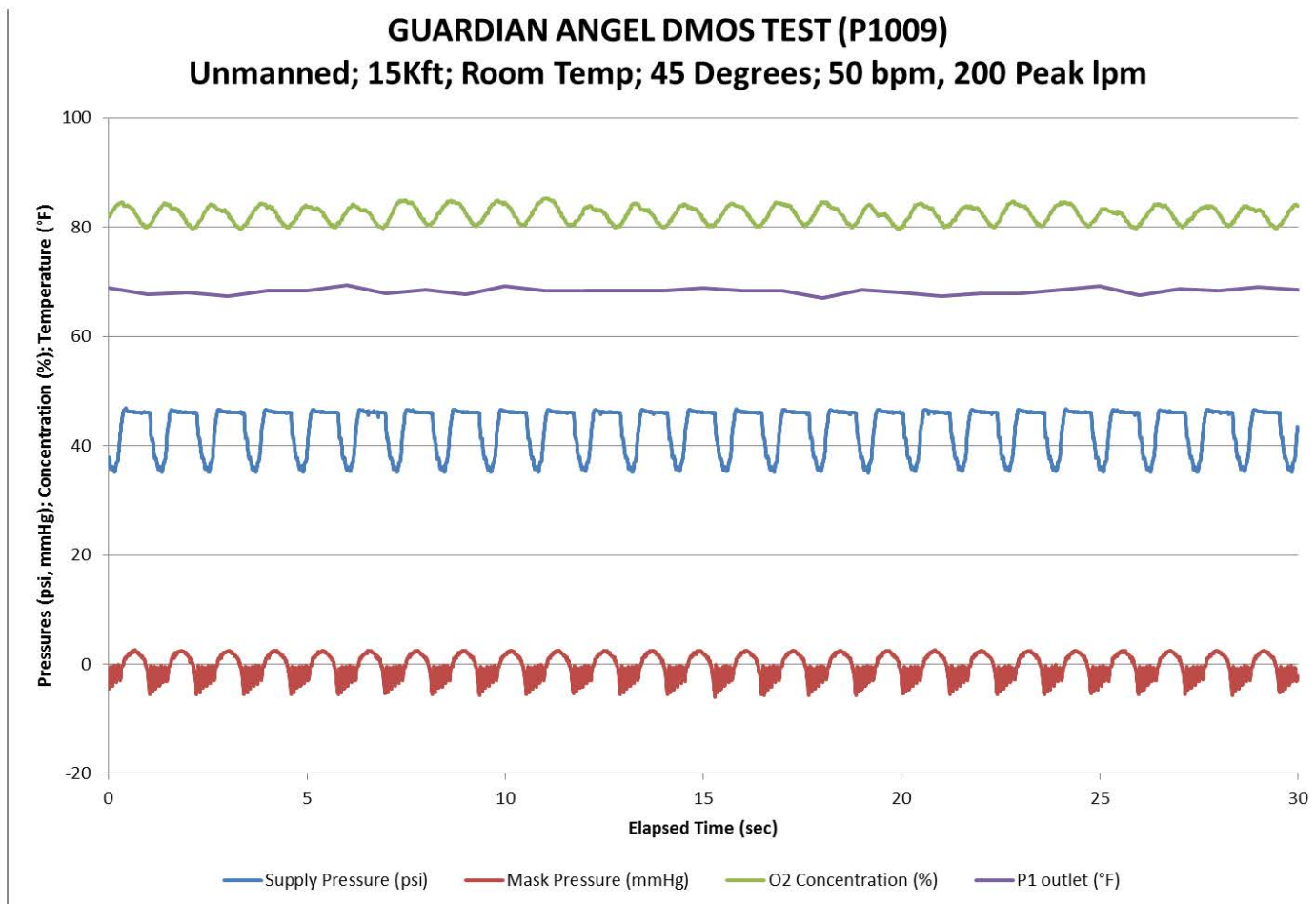


Figure D-121

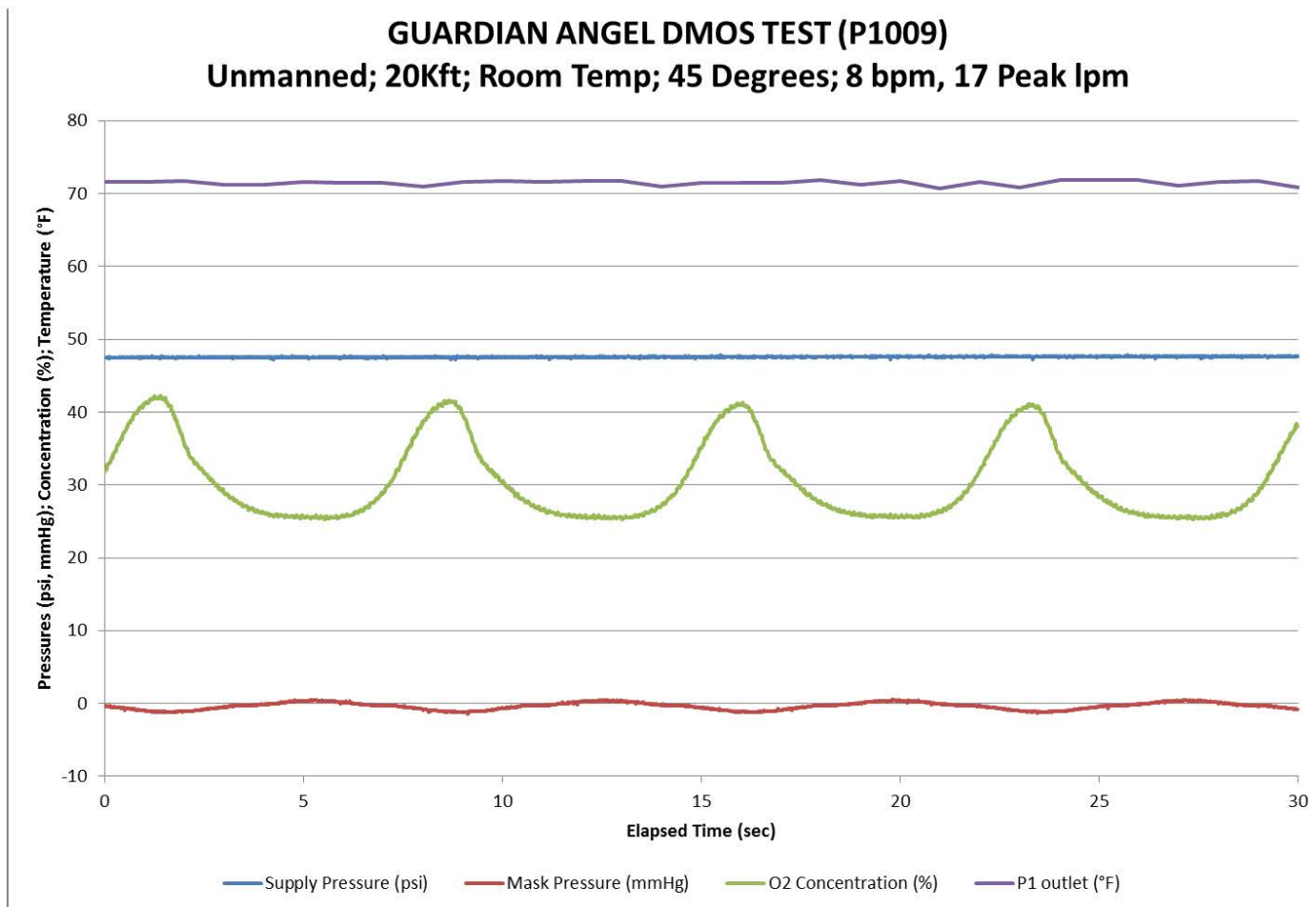


Figure D-122

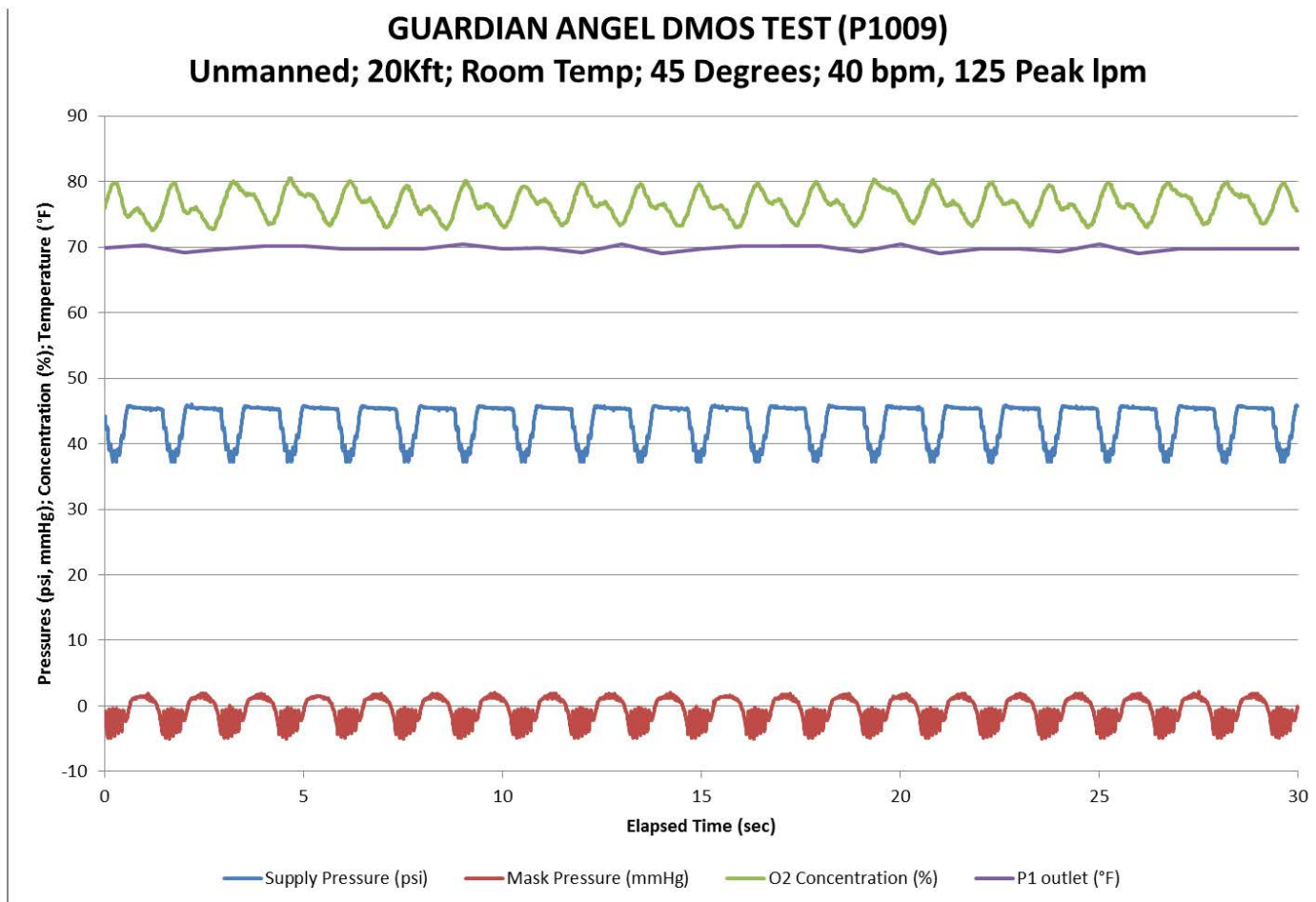


Figure D-123

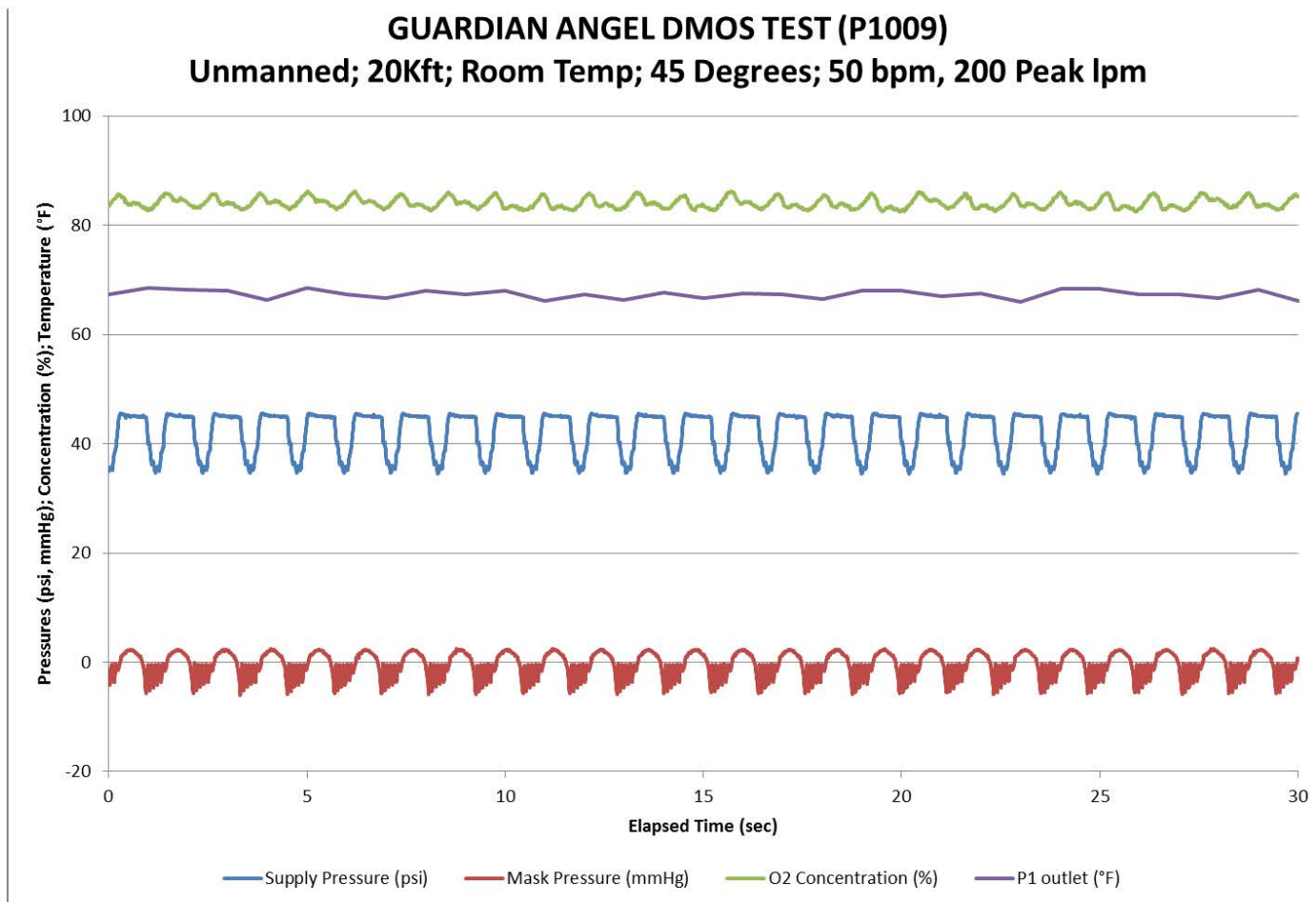


Figure D-124

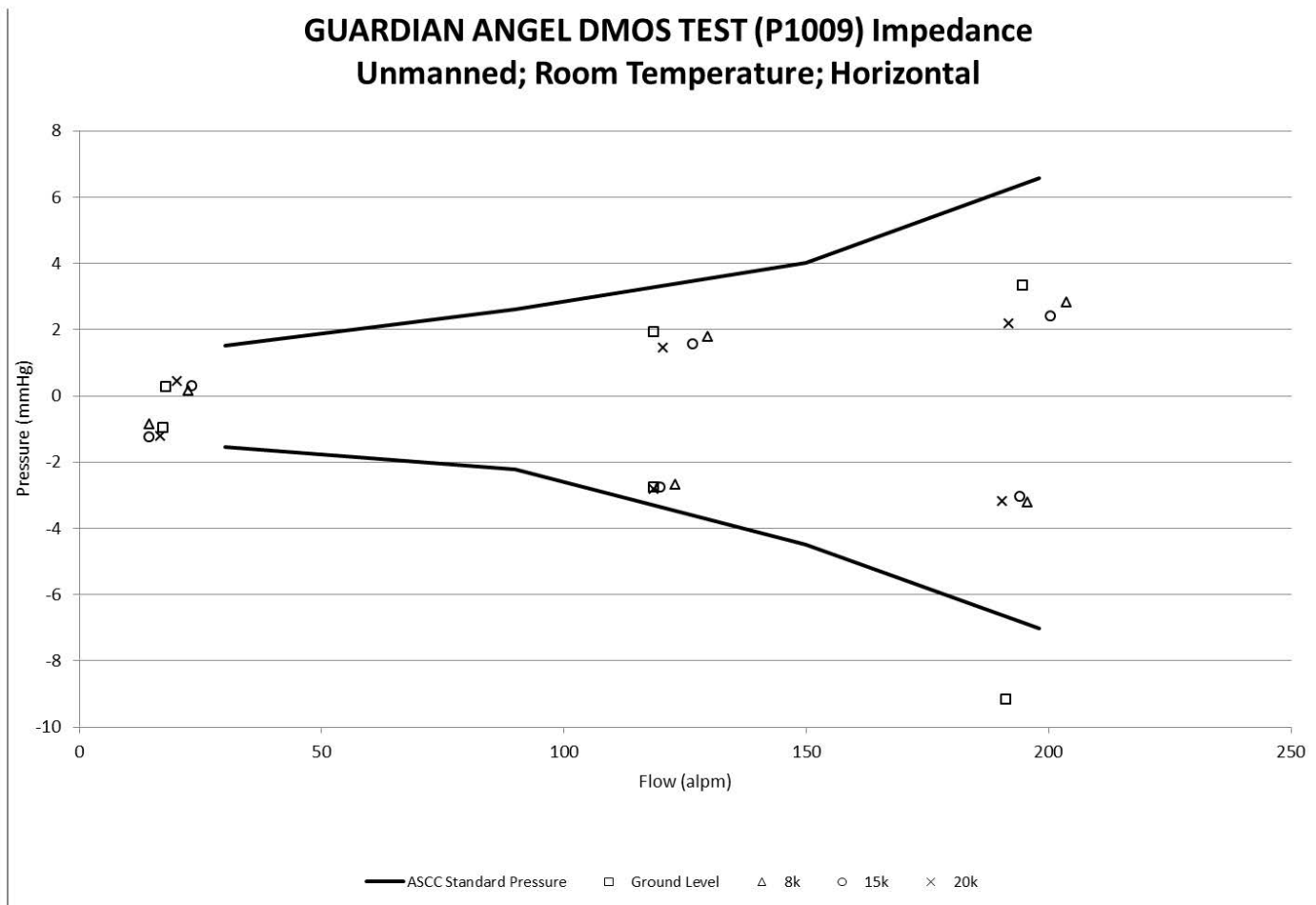


Figure D-125

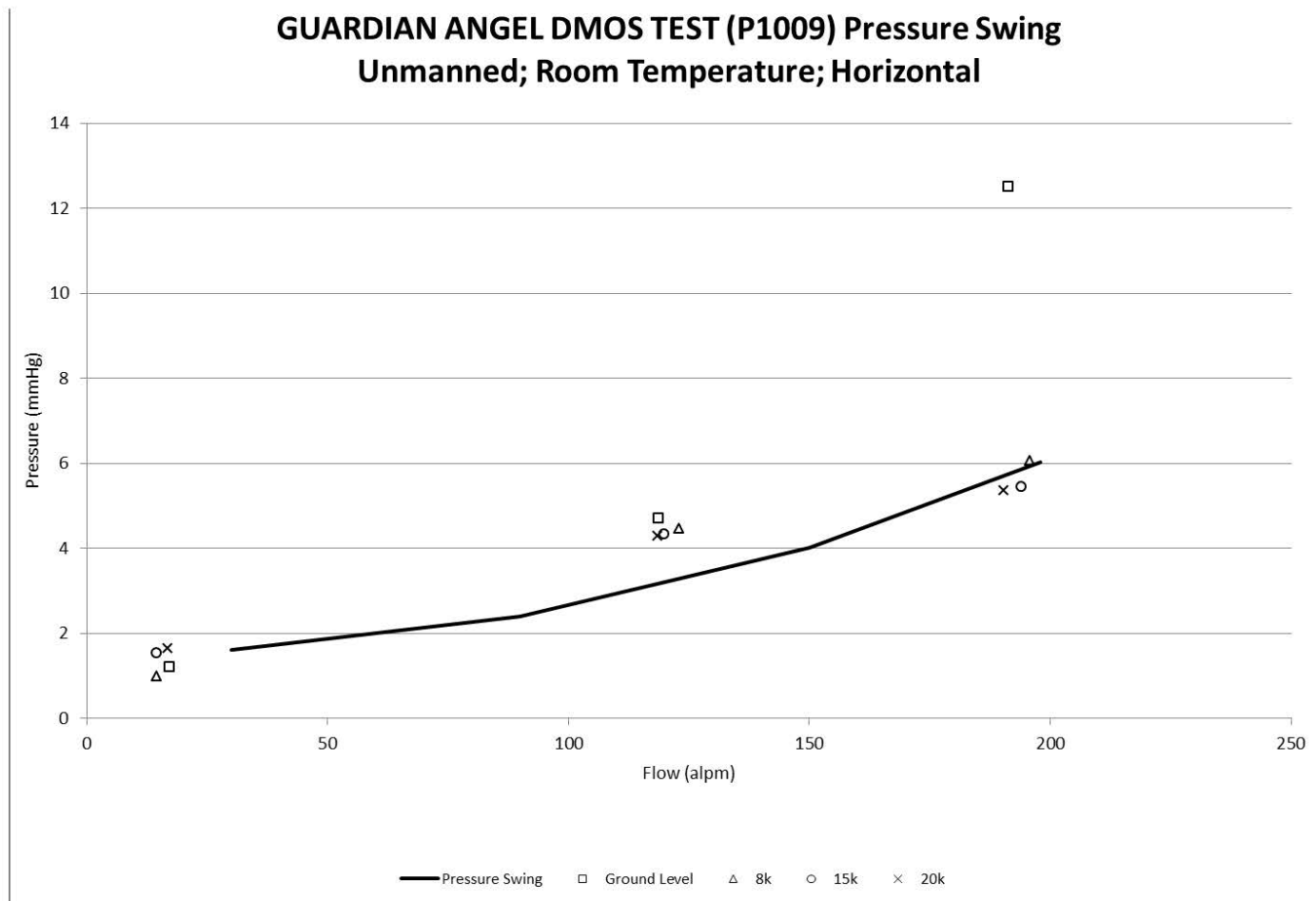


Figure D-126

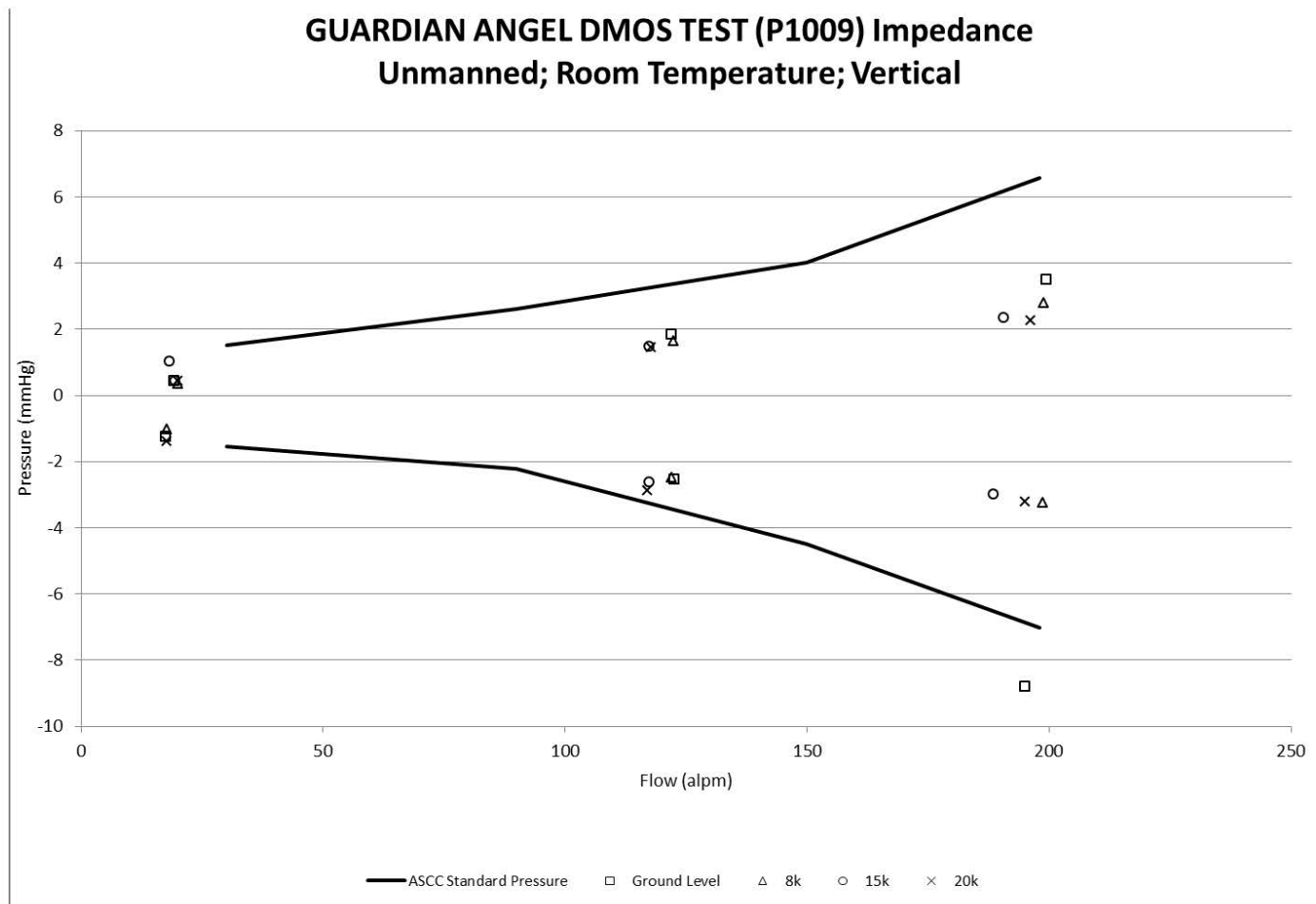


Figure D-127

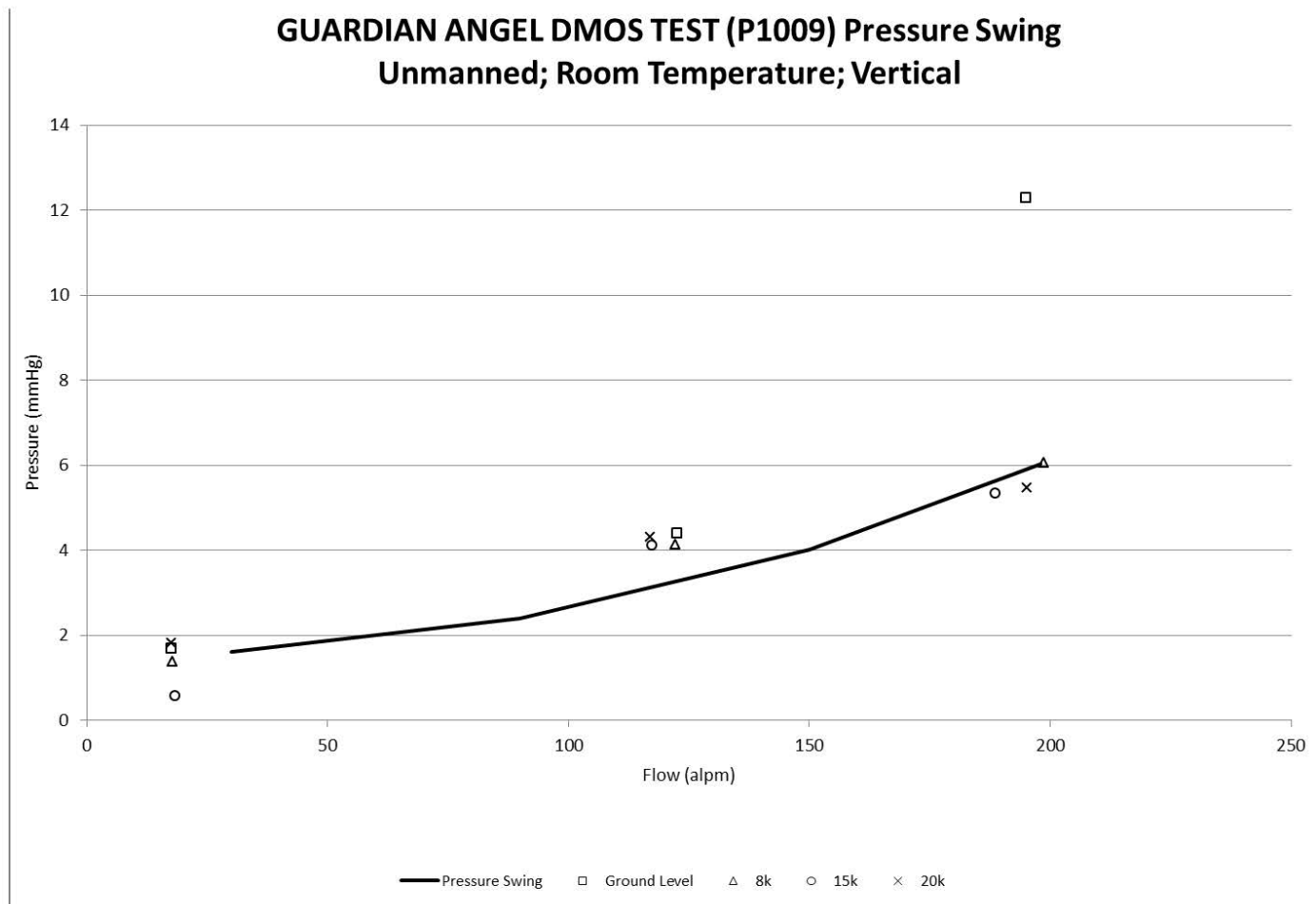


Figure D-128

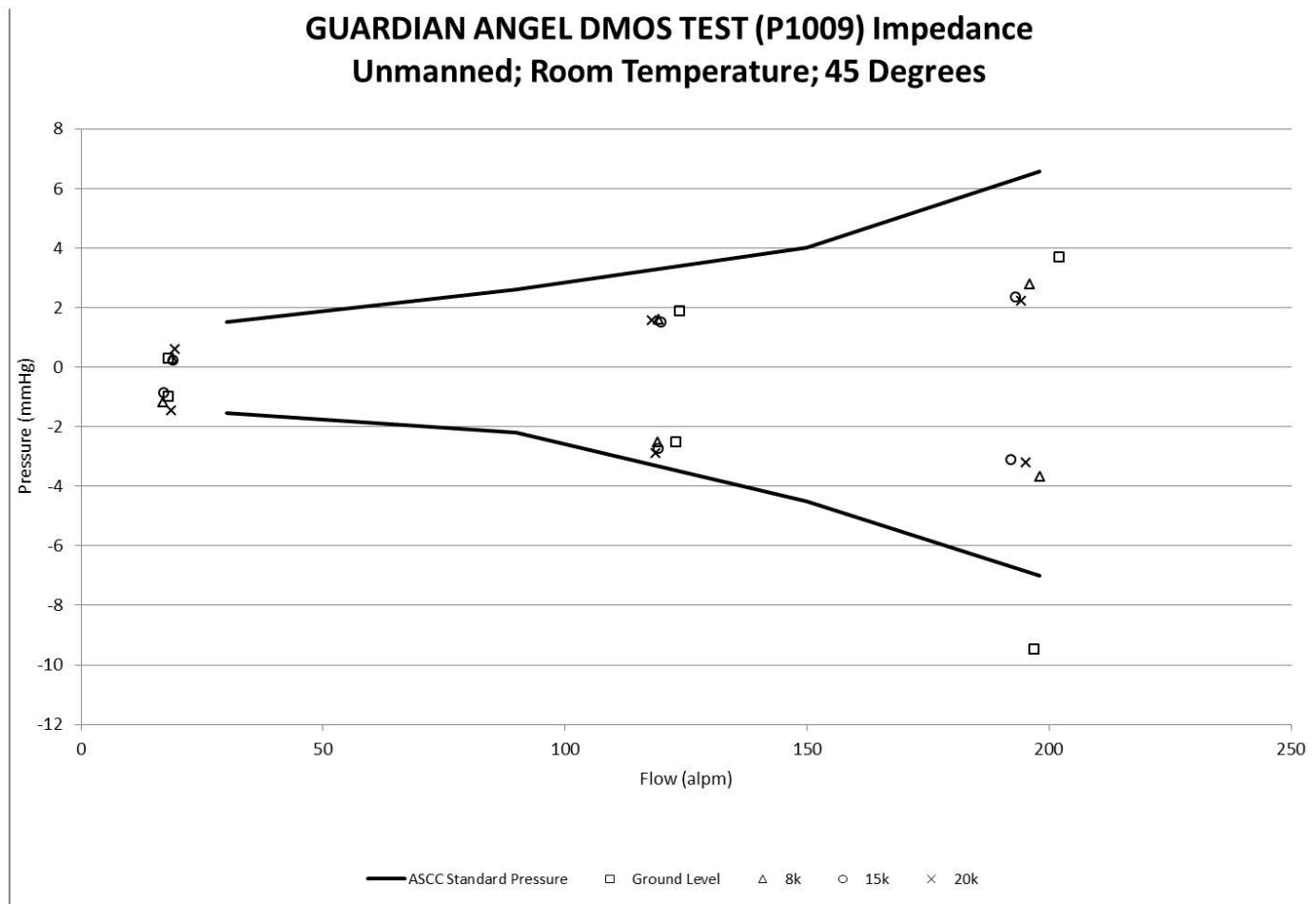


Figure D-129

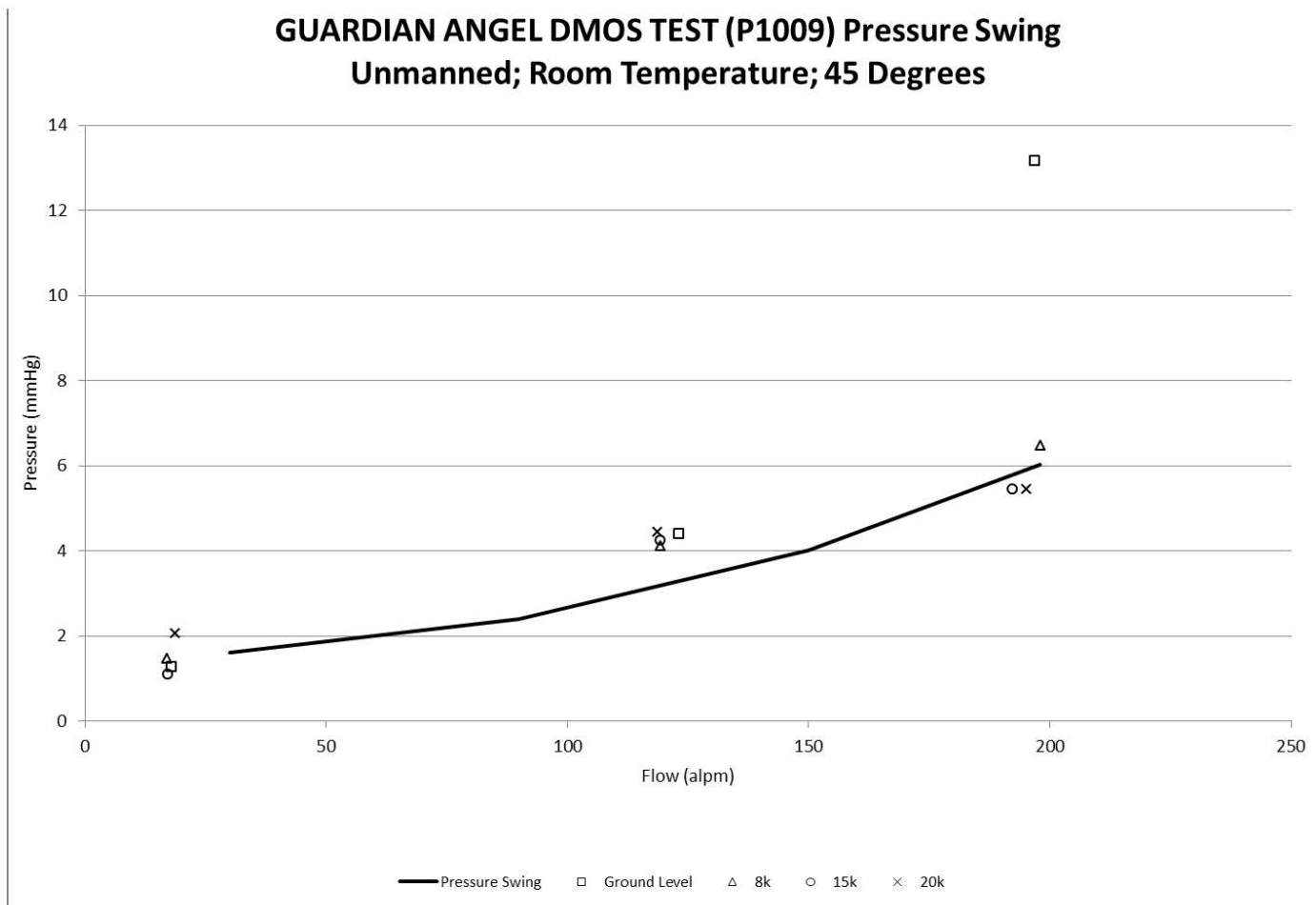


Figure D-130

APPENDIX E: DMOS Manned Data

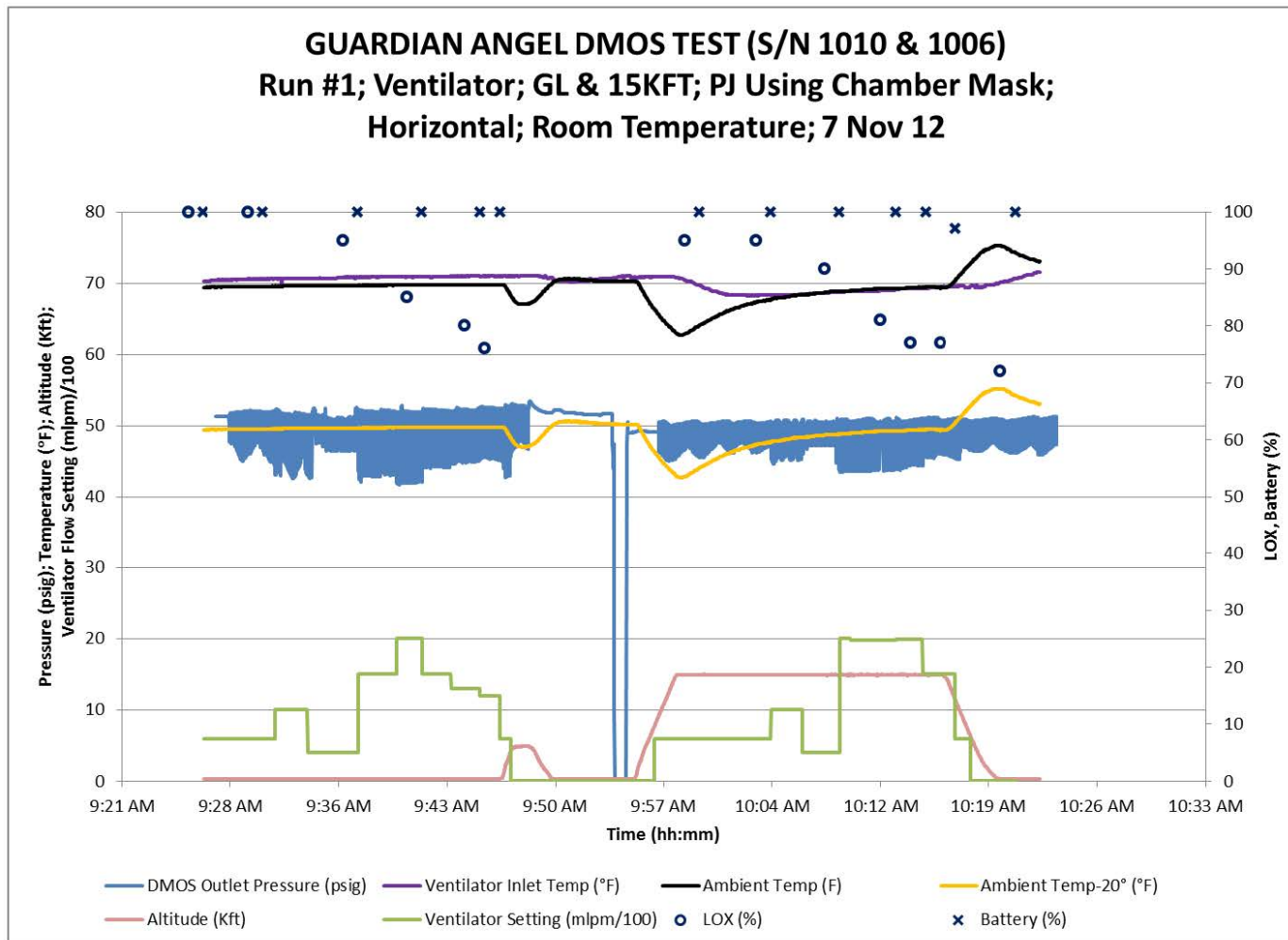


Figure E-1

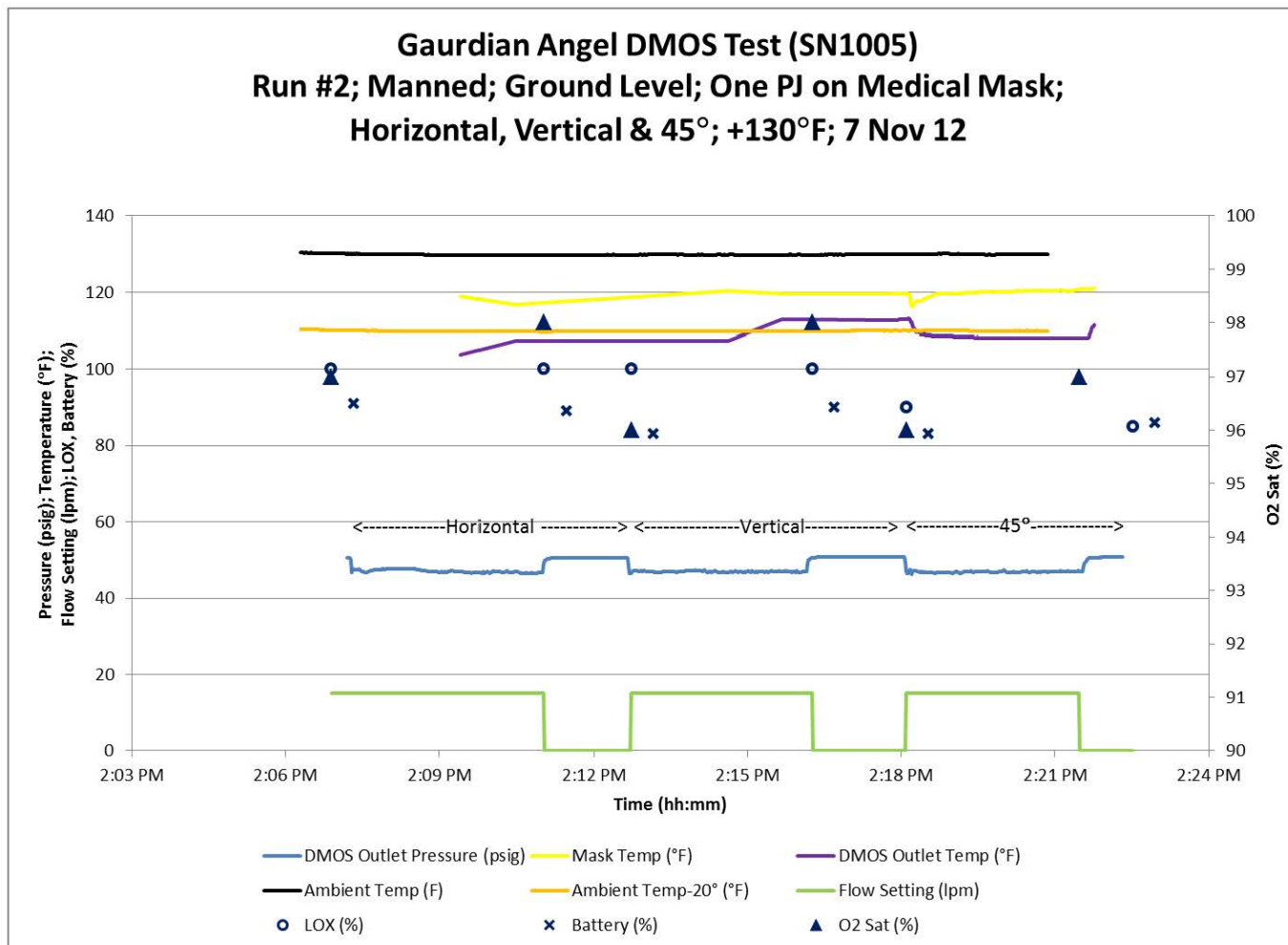


Figure E-2

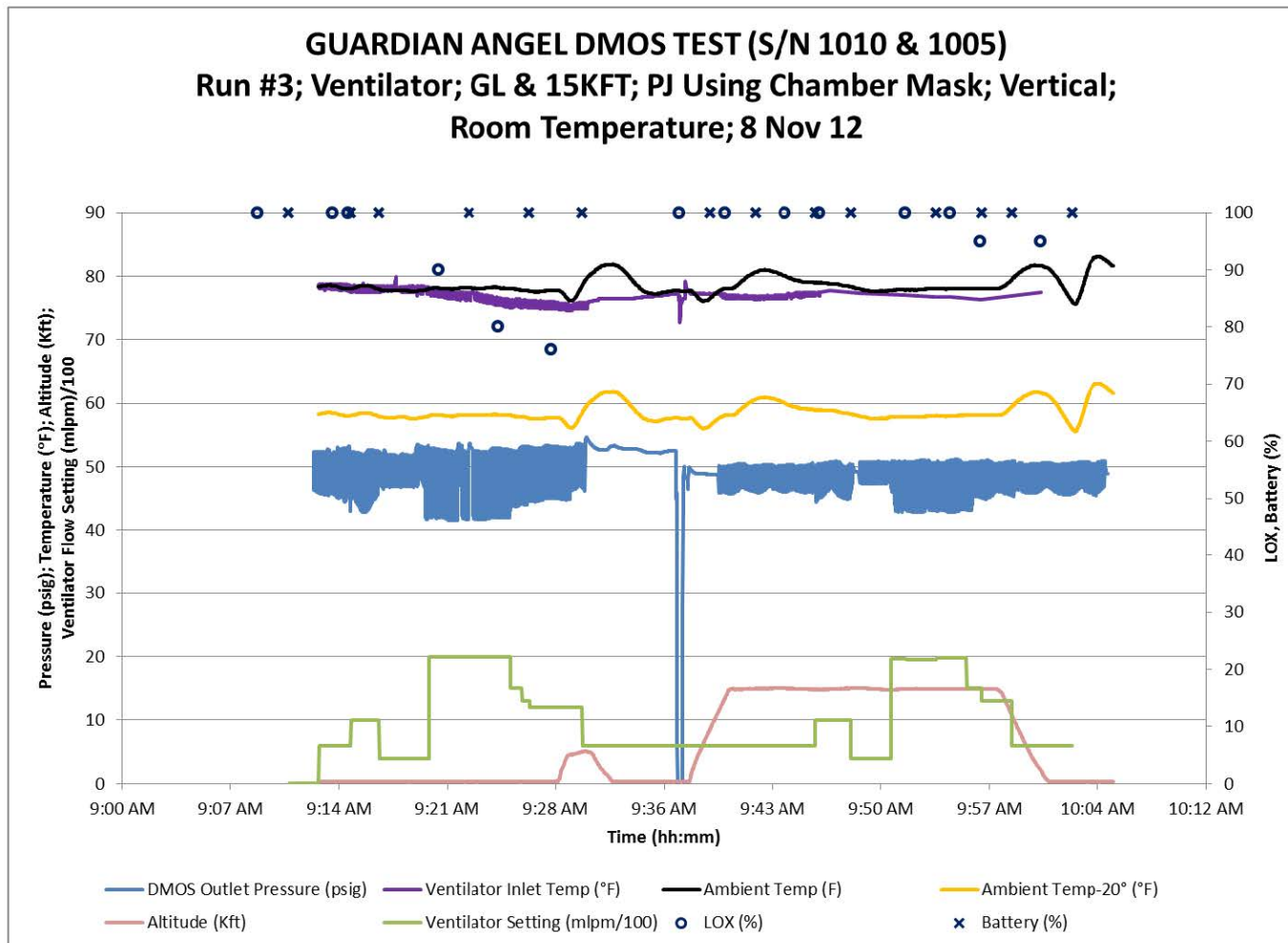


Figure E-3

Gaurdian Angel DMOS Test; SN1006
Run #4; Manned; Ground Level; One PJ on Medical Mask;
DMOS Horizontal, Vertical & 45°; -40°F; 8 Nov 12, PM

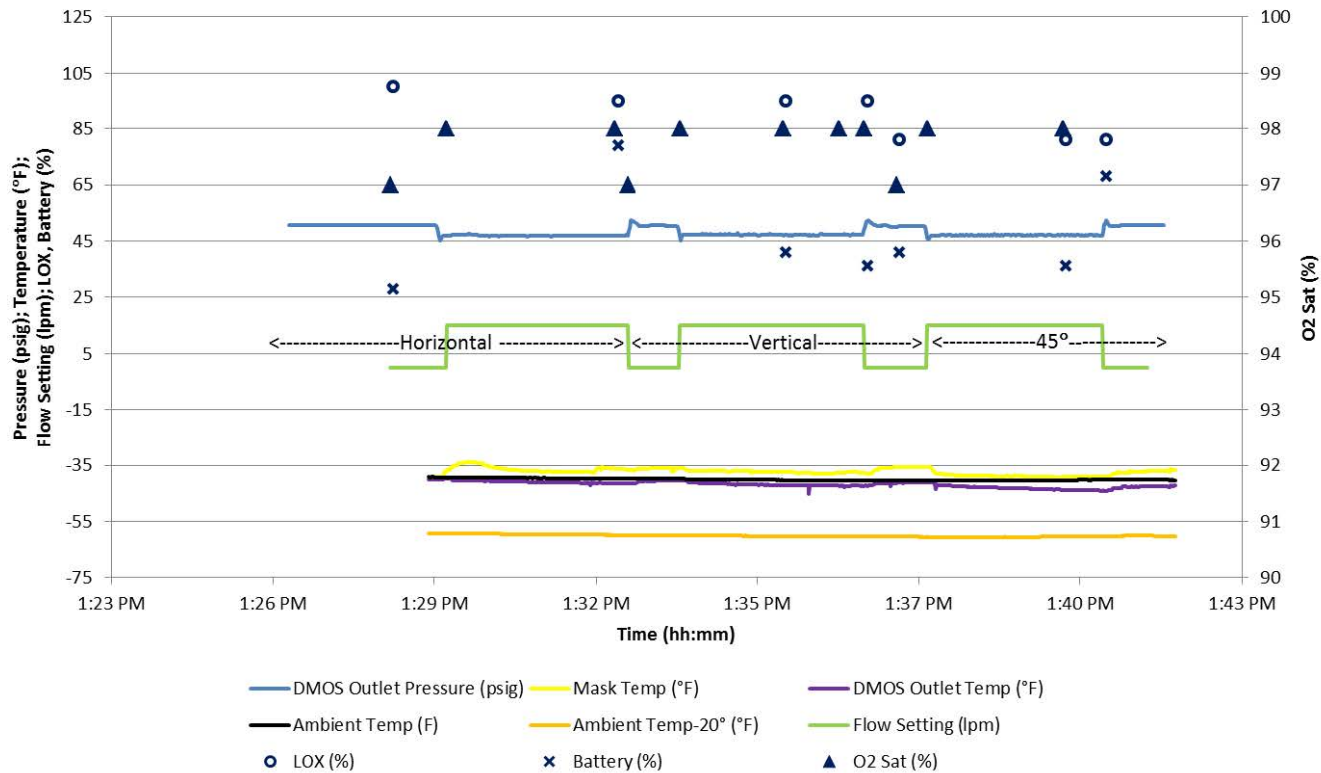


Figure E-4

GUARDIAN ANGEL DMOS TEST (S/N 1010, GL & 1006, 15KFT)
Run #5; Ventilator; GL & 15KFT; PJ Using Chamber Mask; 45°;
Room Temperature; 9 Nov 12

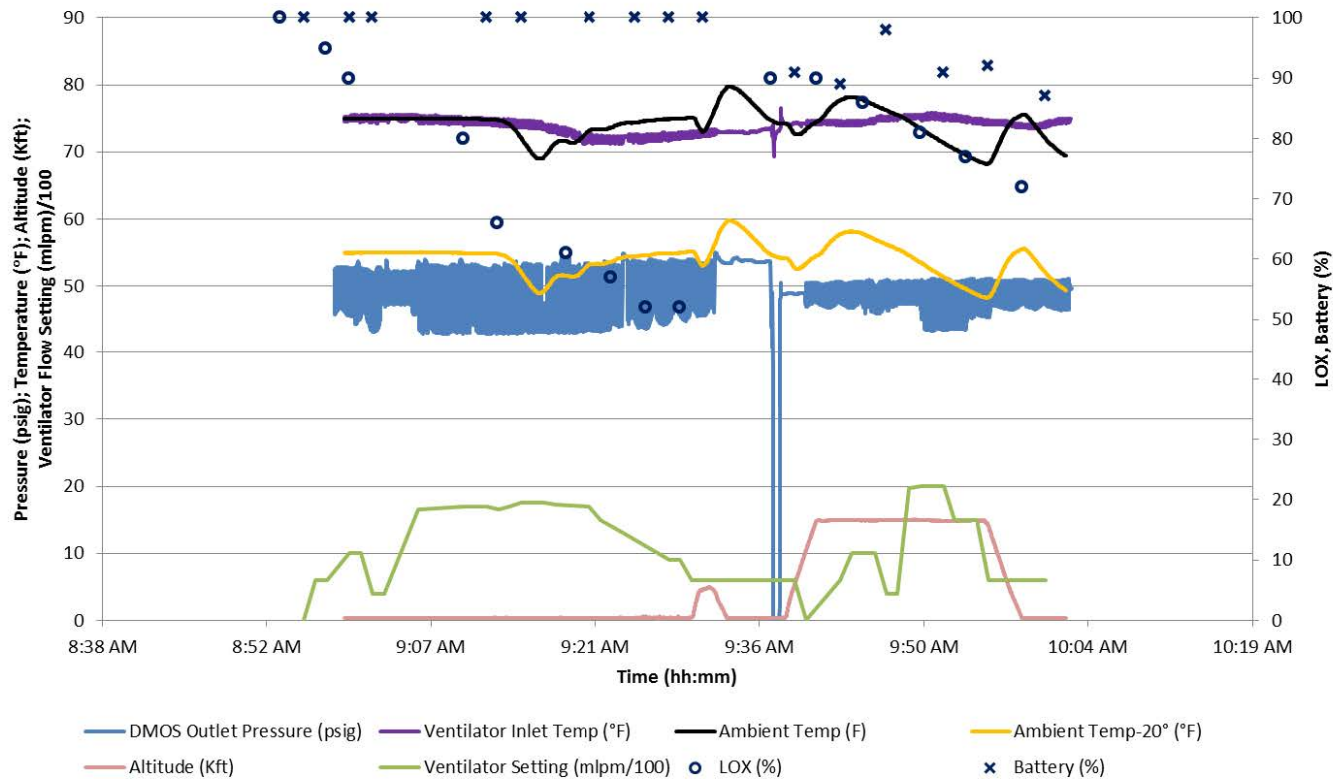


Figure E-5

GUARDIAN ANGEL DMOS TEST (S/N 1010, 15KFT)

Run #6; GL & 15KFT; Horizontal;

Room Temperature; 9 Nov 12

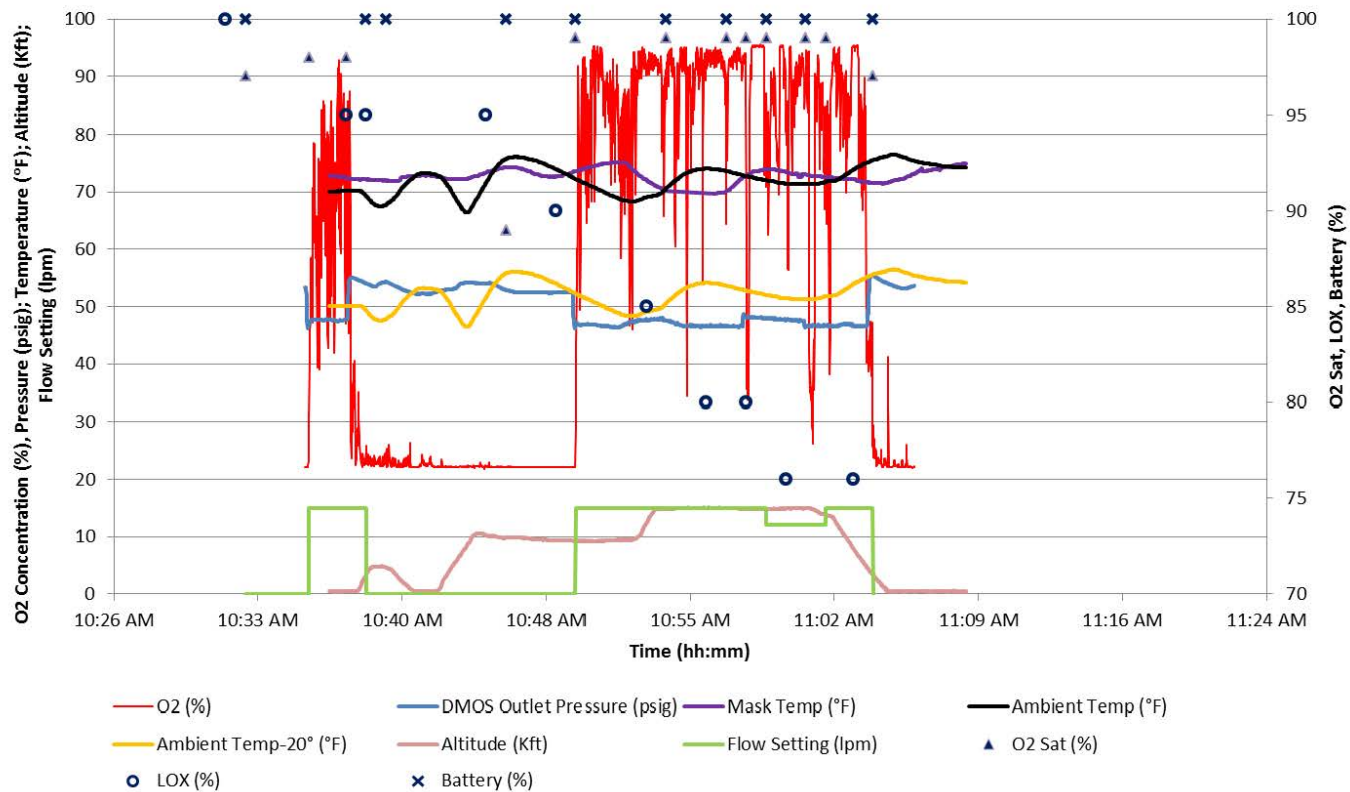


Figure E-6

GUARDIAN ANGEL DMOS TEST (S/N 1010, 15KFT)

Run #7; GL & 15KFT; Vertical;

Room Temperature; 13 Nov 12

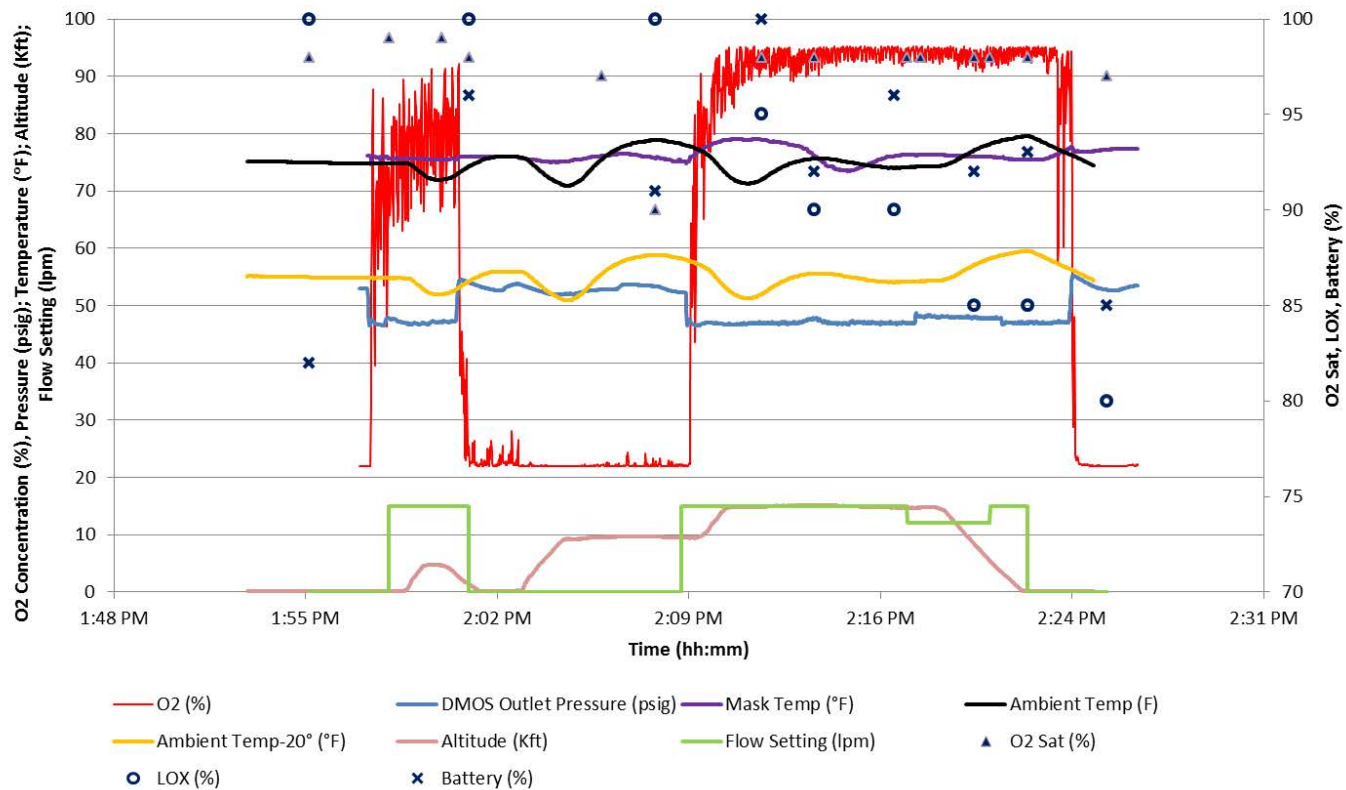


Figure E-7

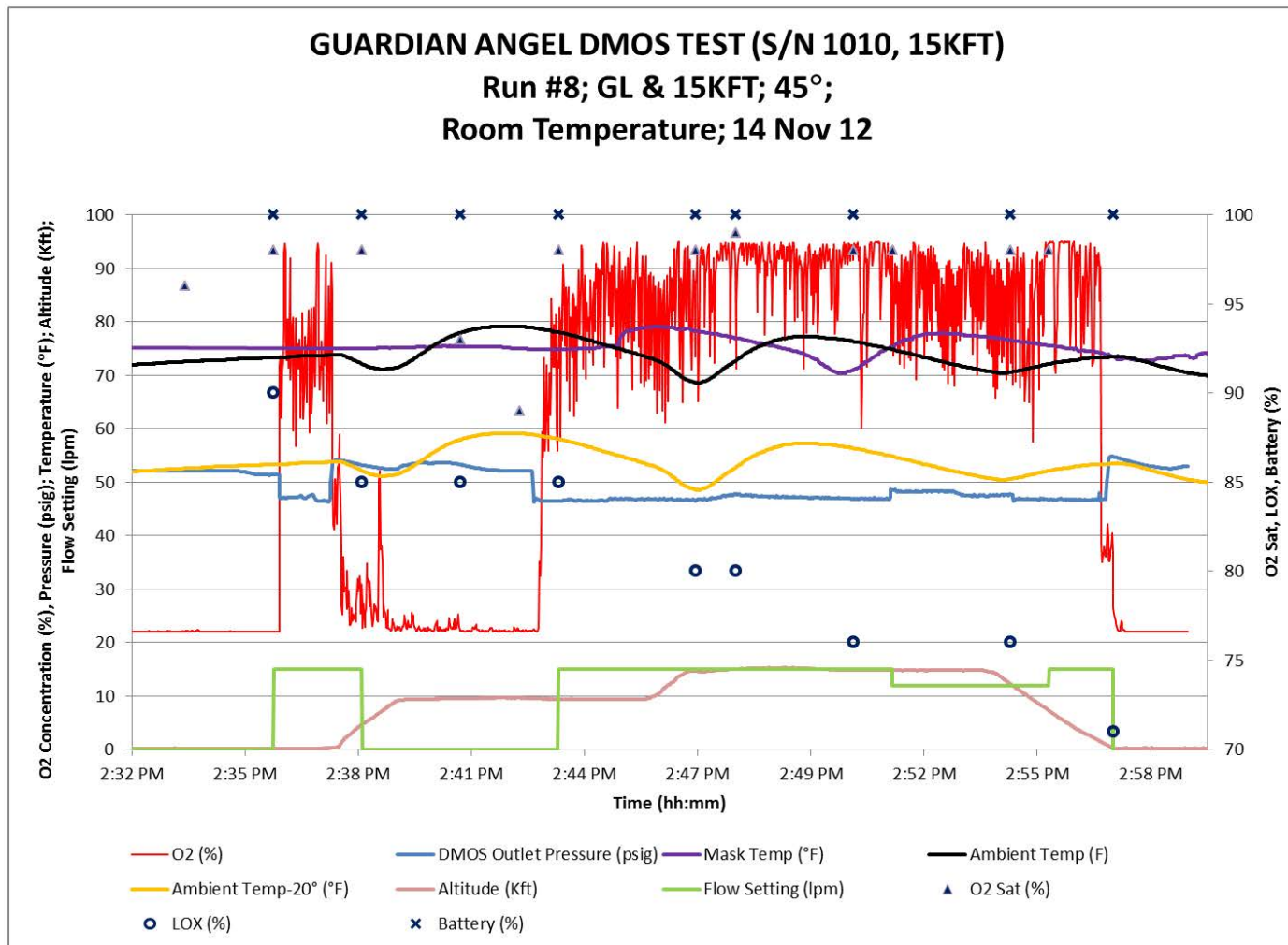


Figure E-8

APPENDIX F: DMOS Questionnaires

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>1</u>	Date/Time <u>7 Nov 2012 - 1025</u>
Test Number: <u>1 - Ventilator Run, Horizontal at GL & 15K</u>	
Participant Oxygen Mask (circle): Non-instrumented <u>N/A</u> Instrumented	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the DMOS? (circle) Yes No If Yes, note the altitude/s where you experienced symptoms and describe them. <u>N/A</u>	
Ventilator tests: Did the ventilator appear to operate normally? (circle) <u>Yes</u> No If No, note any problems.	

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>1</u>	Date/Time <u>7 Nov 1425</u>
Test Number: <u>2</u> - <u>+130 GL</u> - <u>Horizontal</u> <u>Vertical</u> <u>45</u>	
Participant Oxygen Mask (circle): Non-instrumented <u>Instrumented</u>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) Yes <u>No</u> If No, note the altitude/s where you experienced any problems and describe the problem/s. <u>Temp (in my opinion) not be conducive to</u> <u>pt. care. For Temp purposes only.</u>	
Did you experience any symptoms while breathing on the DMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No If No, note any problems. <u>N/A</u>	

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>2 (16)</u>	Date/Time <u>8 Nov 12 1010</u>
----------------------------------	--------------------------------

Test Number: <u>3</u>

Participant Oxygen Mask (circle):	<u>N/A</u>
Non-instrumented	Instrumented

Did you receive an acceptable breathing gas? (circle) Yes No
If No, note the altitude/s where you experienced any problems and describe the problem/s.
<u>N/A</u>

Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No
If No, note the altitude/s where you experienced any problems and describe the problem/s.
<u>N/A</u>

Did you experience any symptoms while breathing on the DMOS? (circle) Yes No
If Yes, note the altitude/s where you experienced symptoms and describe them.
<u>N/A</u>

Ventilator tests: Did the ventilator appear to operate normally? (circle) <u>Yes</u> No
If No, note any problems. <u>VENTILATOR WORKED TO SPECS.</u>

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>2 - LG</u>	Date/Time <u>1345 8 Nov 12</u>
----------------------------------	--------------------------------

Test Number: 4 → -40° GL - Horizontal
Vertical
45°

Participant Oxygen Mask (circle):

Non-instrumented

Instrumented

Did you receive an acceptable breathing gas? (circle) Yes No

If No, note the altitude/s where you experienced any problems and describe the problem/s.

Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No

If No, note the altitude/s where you experienced any problems and describe the problem/s.

OXYGEN IN MASK FELT BETTER THAN AMBIENT AIR

Did you experience any symptoms while breathing on the DMOS? (circle) Yes No

If Yes, note the altitude/s where you experienced symptoms and describe them.

Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No

If No, note any problems.

N/A

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>H2 (LG)</u>	Date/Time <u>7 Nov 12 / 10 AM</u>
-----------------------------------	-----------------------------------

Test Number: <u># 5 - w/vent. later</u> <u>15 K - 45°</u>
--

Participant Oxygen Mask (circle):	<u>N/A</u>
Non-instrumented	Instrumented

Did you receive an acceptable breathing gas? (circle) Yes No
If No, note the altitude/s where you experienced any problems and describe the problem/s.
<u>N/A</u>

Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No
If No, note the altitude/s where you experienced any problems and describe the problem/s.
<u>N/A</u>

Did you experience any symptoms while breathing on the DMOS? (circle) Yes No
If Yes, note the altitude/s where you experienced symptoms and describe them.
<u>N/A</u>

Ventilator tests: Did the ventilator appear to operate normally? (circle) <u>Yes</u> No
If No, note any problems. <u>VENTILATOR WORKED ACCORDING TO SPECS.</u>

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>H1 (SK)</u>	Date/Time <u>9 Nov 12 1115</u>
-----------------------------------	--------------------------------

Test Number: 6

Participant Oxygen Mask (circle):

Non-instrumented

Instrumented

Did you receive an acceptable breathing gas? (circle) Yes No

If No, note the altitude/s where you experienced any problems and describe the problem/s.

Was the oxygen breathing gas at an acceptable temperature? (circle) Yes No

If No, note the altitude/s where you experienced any problems and describe the problem/s.

Did you experience any symptoms while breathing on the DMOS? (circle) Yes No

If Yes, note the altitude/s where you experienced symptoms and describe them.

Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No

If No, note any problems.

N/A

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>3 (SR)</u>	Date/Time <u>13 Nov - 1425</u>
Test Number: [#] <u>7</u> - <u>15k, 9,500 ft, GL</u> <u>Vertical</u>	
Participant Oxygen Mask (circle): Non-instrumented <u>Instrumented</u>	
Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No If No, note the altitude/s where you experienced any problems and describe the problem/s.	
Did you experience any symptoms while breathing on the DMOS? (circle) Yes <u>No</u> If Yes, note the altitude/s where you experienced symptoms and describe them.	
Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No If No, note any problems. <u>N/A</u>	

ATTACHMENT

DMOS QUESTIONNAIRE

Manned Testing of the Dismounted Medical Oxygen System

Participant Number <u>#3 (JR)</u>	Date/Time <u>14 Nov 2012 1500</u>
-----------------------------------	-----------------------------------

Test Number: <u>#8 - 9,500 ft + 15K ft, 45 degree orientation of DMOS</u>

Participant Oxygen Mask (circle):
Non-instrumented <u>Instrumented</u>

Did you receive an acceptable breathing gas? (circle) <u>Yes</u> No
If No, note the altitude/s where you experienced any problems and describe the problem/s.

Was the oxygen breathing gas at an acceptable temperature? (circle) <u>Yes</u> No
If No, note the altitude/s where you experienced any problems and describe the problem/s.

Did you experience any symptoms while breathing on the DMOS? (circle) Yes <u>No</u>
If Yes, note the altitude/s where you experienced symptoms and describe them.

Ventilator tests: Did the ventilator appear to operate normally? (circle) Yes No
If No, note any problems.

N/A

ATTACHMENT

APPENDIX G: OGS Oxygen Sample Analysis Reports

AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA35124001	Date Received:12/15/11 0958 hrs*	Date Sampled: 12/14/2011**
Cust Sample No:Not Specified	Date Reported:12/15/11 1246 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
711 HPW/RHCPT
2150 Fifth Street
Bldg 840
Wright-Patterson AFB, OH 45433

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 81A01093 Tank Pressure:1,200 psi

Method	Test	Min	Max	Result
CGA G-4.3-2000	Odor			None
CGA G-4.3-2000	Purity (% vol)	90.0	96.0	95.2
CGA G-4.3-2000	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2000	Moisture (ppmv)	Report Only		12

Dispositions:
Material meets test requirements

Approved By	Date
Michael Cole	12/15/2011*
\\SIGNED\\	

This report was electronically delivered to:
afpet.afett@wpafb.af.mil, george.miller@wpafb.af.mil, michael.cole@wpafb.af.mil,
mike.casanova@us.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2011LA35287001	Date Received:12/23/11 1045 hrs*	Date Sampled: 12/21/2011**
Cust Sample No:Not Specified	Date Reported:12/23/11 1334 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
711 HPW/RHCPT
2150 Fifth Street
Bldg 840
Wright-Patterson AFB, OH 45433

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 82A01093 Tank Pressure:1,200 psi

Method	Test	Min	Max	Result
CGA G-4.3-2000	Odor			None
CGA G-4.3-2000	Purity (% vol)	90.0	96.0	95.2
CGA G-4.3-2000	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	1
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2000	Moisture (ppmv)	Report Only		13

Dispositions:
Material meets test requirements

Approved By	Date
Mike Casanova	12/23/2011*
\\SIGNED\\	

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afpet.aftt@wpafb.af.mil, george.miller@wpafb.af.mil, mike.casanova@us.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA35443001	Date Received:01/05/12 1337 hrs*	Date Sampled: 12/30/2011**
Cust Sample No:Not Specified	Date Reported:01/05/12 1527 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
711 HPW/RHCPT
2150 Fifth Street
Bldg 840
Wright-Patterson AFB, OH 45433

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 82A01093 Tank Pressure:1,100 psi

Method	Test	Min	Max	Result
CGA G-4.3-2000	Odor			None
CGA G-4.3-2000	Purity (% vol)	90.0	96.0	95.6
CGA G-4.3-2000	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2000	Moisture (ppmv)	Report Only		7

Dispositions:
Material meets test requirements

Approved By	Date
Michael Cole	01/05/2012*
\\SIGNED\\	

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mike.casanova@us.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA35603001	Date Received:01/13/12 1258 hrs*	Date Sampled: 01/12/2012**
Cust Sample No:GUARDIAN ANGEL	Date Reported:01/13/12 1606 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
711 HPW/RHCPT
2150 Fifth Street
Bldg 840
Wright-Patterson AFB, OH 45433

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 82A01095 Tank Pressure:1,200 psi

Method	Test	Min	Max	Result
CGA G-4.3-2000	Odor			None
CGA G-4.3-2000	Purity (% vol)	90.0	96.0	95.3
CGA G-4.3-2000	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2000	Moisture (ppmv)	Report Only		1

Dispositions:
Material meets test requirements

Approved By	Date
Miguel Acevedo, Chief	01/13/2012*

\\SIGNED\\

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mike.casanova@us.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA40749001	Date Received:11/02/12 1246 hrs*	Date Sampled: 08/09/2012**
Cust Sample No:OXYGEN	Date Reported:11/09/12 1117 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
413 FLTS Det 1
4450 Dyes Blvd
Nellis AFB, NV 89191

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 12V0035 Tank Pressure:1,700 psi

Method	Test	Min	Max	Result
CGA G-4.3-2007	Odor			None
CGA G-4.3-2007	Purity (% vol)	90.0	96.0	95.2
CGA G-4.3-2007	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2007	Moisture (ppmv)	Report Only		1

Dispositions:
For information purposes only.

Approved By	Date
Christopher M. Smith	11/09/2012*
\\SIGNED\\	

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johnathan.rohde@nellis.af.mil, melissa.teague@wpafb.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA40907001	Date Received:11/15/12 1415 hrs*	Date Sampled: 10/31/2012**
Cust Sample No:OXYGEN	Date Reported:11/15/12 1643 hrs*	Protocol:GA-OXY-0036
GENERATING SYSTEM		

Sample Submitter:
IS&E
2485 Gillingham Drive
Bldg 170
Brooks City Base, TX 78235

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 12V0049 Tank Pressure:1,000 psi

Method	Test	Min	Max	Result
CGA G-4.3-2007	Odor			None
CGA G-4.3-2007	Purity (% vol)	90.0	96.0	95.1
CGA G-4.3-2007	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2007	Moisture (ppmv)	Report Only		11

Dispositions:
Material meets test requirements

Approved By	Date
Miguel Acevedo, Chief	11/15/2012*
\\SIGNED\\	

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miguel.acevedo@wpafb.af.mil

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA41088001	Date Received:11/28/12 1558 hrs*	Date Sampled: 11/15/2012**
Cust Sample No:OXYGEN	Date Reported:11/30/12 1654 hrs*	Protocol:GA-OXY-0036

Sample Submitter:
IS&E
2485 Gillingham Drive
Bldg 170
Brooks City Base, TX 78235

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 12V0035 Tank Pressure:1,600 psi

Method	Test	Min	Max	Result
CGA G-4.3-2007	Odor			None
CGA G-4.3-2007	Purity (% vol)	90.0	96.0	95.8
CGA G-4.3-2007	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2007	Moisture (ppmv)	Report Only		2

Dispositions:

Coordinated with Mike Sanders (PTPT), phone: DSN 785-8050, COM 937-255-8050.
Material meets test requirements
Cylinder returned purged and under vacuum.

Approved By	Date
Miguel Acevedo, Chief	11/30/2012*

\\SIGNED\\

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AFPET LABORATORY REPORT
AFPA/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No:2012LA41088002	Date Received:11/28/12 1558 hrs*	Date Sampled: 11/15/2012**
Cust Sample No:OXYGEN	Date Reported:11/30/12 1655 hrs*	Protocol:GA-OXY-0036

GENERATING SYSTEM

Sample Submitter:
IS&E
2485 Gillingham Drive
Bldg 170
Brooks City Base, TX 78235

Reason for Submission: Special Request
Product: Oxygen, Liquid
Specification: USP Oxygen

Sample Eq Ser No: 12V0049 Tank Pressure:1,700 psi

Method	Test	Min	Max	Result
CGA G-4.3-2007	Odor			None
CGA G-4.3-2007	Purity (% vol)	90.0	96.0	95.4
CGA G-4.3-2007	Minor Constituents (By IR)			
	Carbon Dioxide (ppmv)		300	0
	Carbon Monoxide (ppmv)		10	0
CGA G-4.3-2007	Moisture (ppmv)	Report Only		6

Dispositions:

Coordinated with Mike Sanders (PTPT), phone: DSN 785-8050, COM 937-255-8050.
Material meets test requirements
Cylinder returned purged and under vacuum.

Approved By	Date
Miguel Acevedo, Chief	11/30/2012*

\\SIGNED\\

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LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

711 HPW/RHCP	711 th Human Performance Wing, Applied Neuroscience Branch
ALPM	ambient liters/minute referenced to ambient pressure and temperature
BAT	battery life percentage
CSAR	combat search and rescue
DMOS	Dismounted Medical Oxygen System
GAIOS	Guardian Angel Integrated Oxygen System
LOX	liquid oxygen
LPM	liters/minute
lbs	pounds
MMOS	Mounted Medical Oxygen System
OGS	Oxygen Generating System
PJs	pararescuemen
PT	physiology technician
psig	pounds per square inch gauge
SLPM	standard liters/minute referenced to 1 atmosphere and 75°F
USP	U. S. Pharmacopeia